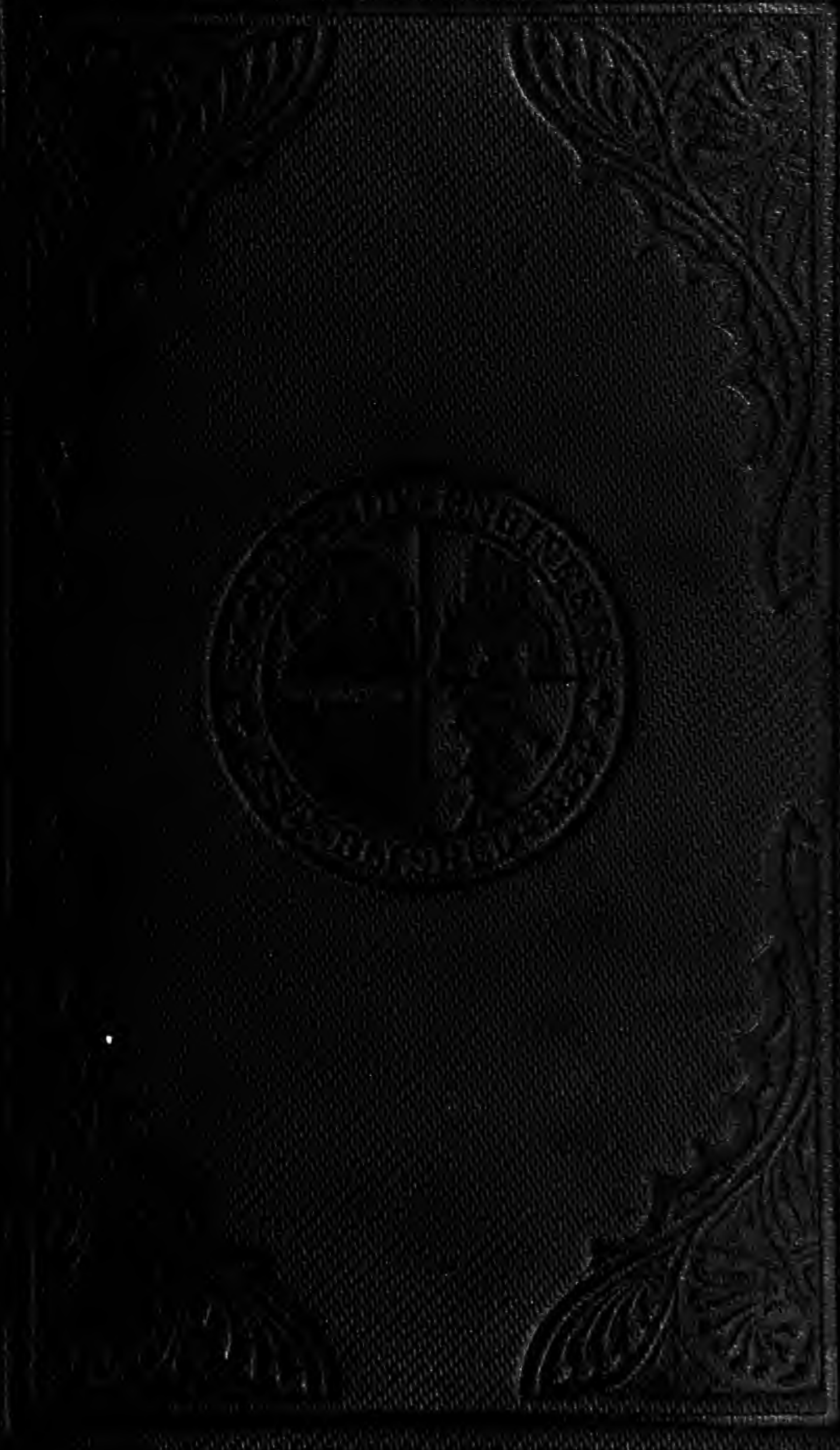

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Journal and

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AND

GENERAL INDEX, 1857 TO 1907

EDITED BY

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PREMIUMS FOR 1907.

At a Meeting of the Society, held on February 3, 1908, the following Premiums were presented, viz.:—

The President's Gold Medal to:

R. W. A. Brewer, for his paper on Liquid Fuels for Internal Combustion Engines.

The Bessemer Premium of Books to:

E. J. Stead, for his paper on The Connaught Bridge, Natal.

A Society's Premium of Books to:

C. A. St. George Moore, for his paper on Working Experiences with Large Gas Engines.

A Society's Premium of Books to:

H. Blake Thomas, for his paper on Subaqueous Operations.

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ESTABLISHED MAY 1854.

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THE ROYAL UNITED SERVICE INSTITUTION, WHITEHALL.

1st JANUARY, 1908.

TRANSACTIONS, &c.

February 4th, 1907.

INAUGURAL ADDRESS.

BY RICHARD ST. GEORGE MOORE, PRESIDENT.

GENTLEMEN,—In selecting the subject of my address for this evening, I have availed myself to the utmost of the unwritten law relating to this selection, referred to by Mr. Perry F. Nursey in his Presidential Address read before you so long ago as 1886, and have adopted for my subject one which relates more directly to the practice than to the science of engineering. I have designated it, for want of a better title, "Some Considerations of the Status of Professional or Consultant Engineers, and how to improve it."

In taking the subject of professional engineering in contradistinction to either manufacturing or commercial engineering, which certainly are of equal importance, both scientifically and otherwise, I have followed another of the laws of the Society, which is that Presidents in their addresses shall deal with subjects with which they have been connected. With the exception of one year during my pupilage, my whole life as an engineer has been passed in the professional branch, therefore I have selected it for consideration. With such a subject I cannot hope to do more than touch on the fringe, but trust that my effort will induce other abler brains and more influential people to take it up and give it the attention it deserves.

All engineers, and I say intentionally "engineers," instead of civil engineers, because there is a tendency even among engineers to understand by civil engineers only men working as professional engineers on structural works, whereas it was originally adopted to mean all engineers, structural or mechanical, other than military engineers. In the discussion held last June on the modification of the constitution of the American

Society of Engineers, published in vol. xxxii., No. 6, of August 1906, Mr. J. C. Trautwine, a member of the committee, says: "If I understand rightly, the term civil engineer was invented for the purpose of designating those few and inconspicuous individuals who at that time, had the hardihood to apply the science and art of engineering to useful purposes, in order to distinguish them from 'the engineers' who devoted themselves solely to destructive purposes." The charter of the Institution of Civil Engineers says: "That species of knowledge which constitutes the profession of a civil engineer being the means of production and of traffic in states both for external and internal trade, as applied in the construction of roads, bridges, aqueducts, canals, river navigation, and docks, of ports, harbours, moles, breakwaters, and lighthouses, etc., and the art of navigation by artificial power, construction and adaptation of machinery, etc." Taking Nuttall's definition of a civil engineer as the popular one, he says: "One employed in delineating plans and superintending the construction of public works." Therefore I say "engineers" in order to appeal without any misunderstanding to all those who are engaged in the pursuit of scientific engineering. All engineers should join together to raise the status of engineering science in the minds of the public who benefit by it, and for ever make it impossible for such sentences as appeared in the 'Daily Mail' of Nov. 13, 1906, quoting from 'Engineering,' to appear in a daily paper. "It must be confessed," says 'Engineering,' "that with some engineers things have occasionally not been thought unworthy or improper, which although not in themselves dishonest, would be impossible among lawyers or doctors, and which would be impossible among engineers, if their organisation were as complete, and their etiquette as strict, as in the older professions."

In this address I do not propose to touch on such subjects as the all-absorbing one of the education and technical training of the engineer. Mr. Maurice Wilson, our President last year, who has had such a large experience on this question, dealt with it in his address. The researches and publications on the subject are numerous. I start, therefore, with the assumption (which, after Sir William White's article in 'The 19th Century and Afterwards,' is not a presumptuous one) that it is generally understood what is necessary for a good technical education and training. My subject is one which can only be illustrated by details, but before attempting to select any detail for illustration I propose describing the position of the professional or consultant engineer in England, Germany, France, and America, as accurately as is possible in the length of time at my disposal, and tracing the lines on which development has taken place in these countries.

I propose taking them in the order of the date of the founding of the senior or parent Engineering Institution of each country. The Institution of Civil Engineers was founded in 1818 and its first charter was granted by George IV. in 1828. In Germany in 1846, there was founded a small society of engineers which was called the "Hütte," and in 1856 due to the activity of two members of the "Hutte," The Verein deutscher Ingenieure was founded. In France, The Société des Ingénieurs Civils, was founded in 1848 and recognised by public decree in 1860. The American Society of Civil Engineers was founded in 1867. At the present date admission to the Institution of Civil Engineers is by examination, combined with a review of the candidate's past work, and election. In the Société des Ingénieurs Civils de France, there are Membres d'Honneur, and Membres Sociétaires, divided into two classes Titulaires and Assistants. To be elected as a Membre Sociétaire Titulaire it is necessary to have had five years' practical experience. If the candidate has had less experience than this he is elected a Membre Sociétaire Assistant until he has completed his five years of experience. In the Society of American Engineers, as Member, a candidate must be not less than thirty years of age and have been not less than ten years in active practice, graduation at a recognised School of Engineering to count for two years. As Associate Member not less than six years' active practice and two years' reduction for graduation are the conditions.

I am using the term "consultant" as applied to any engineer who is consulted professionally, be it by a company or corporation who pay him a salary, by a company or corporation who retain his services for a special work, or by another engineer, but not an engineer who contracts for the construction of works. In England, where engineering will, in another twelve years, have existed as a profession for 100 years, the development has followed on free and independent lines, it is the home of the consultant in private practice. Apart from the Indian Official Engineers and the Royal Engineers, who do not come within the scope of my subject, there are a comparatively few engineers in the service of the Government. The most important of these being the Inspecting Engineers of the Local Government Board, whose duties, as their title implies, are inspecting, not constructing engineers, nearly all large Government works being entrusted to one or other of the better known firms of private consultant engineers. Some municipalities have salaried consulting engineers, and also the large railway companies; but both of these frequently employ engineers in private practice. There is no prescribed training or qualifications for any Government or municipal appointment. No universally accepted basis for remuneration, although for constructional work a percentage basis is largely adopted; and for consultative work, a fee for the report, or a fee for each professional day of six hours.

From the courteous reply of the Secretary of the "Verein deutscher Ingenieure" (Union of German Engineers), I understand that in Germany they have a Ministerium der öffentlichen Arbeiten (Ministry of Public Works), which controls, as its name implies, the expenditure of public money on works. To this is attached a complete corps of civil engineers, to enter which it is necessary to hold an Engineering Diploma from one of the Prussian technical schools, and further, to pass a Government examination. In this corps there are nearly 1000 engineers. The result, as is natural from there being such an extensive organisation for carrying out public works—although I am informed that there are a large number of civil engineers in private practice—must be that there are comparatively few compared with England. There are no qualifications necessary to practise as a consultant, and generally speaking, they are in the same position as they are in this country.

While engaged professionally in France, I was brought into contact with several members of the engineering profession there. These engineers formed a committee, appointed by the Prefect of Police to investigate the work on which I was engaged in the interests of the public safety. None of these engineers were in private consulting practice, as might be the case here, but were all Government officials, one being a Chief Engineer of the Ponts et Chaussées, and one a Professor of the Ecole Centrale. At a later date I was again retained to do work in Paris, and I then inquired why they did not employ a French engineer; the explanation was that there were comparatively few civil engineers in private practice in Paris, that nearly all held Government positions. In reply to a letter I wrote to M. Dax, the Secretary of the Society of Civil Engineers, he kindly sent the Mémoires of that society for November 1887, in which, in reply to the Austrian Society of Civil Engineers, they had given a very full detailed account of how public works were designed and supervised in France, and which gives a very clear idea of the position of the civil engineer there. In France the Ministry of Public Works controls the national roads, state railways, the laying out of private railways, the whole of the ports, docks, harbours, and canals—not the whole of the Government docks, harbours, canals, etc., but whole in the broadest sense of the word—all the water and water-power in the country, whether used for driving mills or other works, and for irrigation, besides a number of other matters. The Minister, who is not a technical man, is assisted in all these works by a Government engineering staff, who are technically trained on definite lines, and not only are these engineers employed directly under the Ministry of Public Works, but when certain works of importance are carried out, certain of these engineers are seconded to assist the people engaged on such works. This practically covers the whole of the engineering work done here by the consultant in private practice, and at once explains why so few exist in France. There are a number of trained engineers attached to the private railways, large workshops, and contracting firms. In France there is no legal tariff or custom for the remuneration of consulting engineers, and as far as I can ascertain, no acknowledged standard of training for a consultant in private practice.

Mr. Hunt, the Secretary of the American Society of Civil Engineers, has been kind enough to give me some information as to the position of the civil engineer in America. There the condition materially differs from both the condition obtaining in England, France, or Germany. The greater portion of the engineers practising are salaried men, probably employed by firms of contractors who contract both for the engineering and the construction. There is no legal qualification required either for private practice or to advise a town council, but Mr. Hunt sums up the position in very few words by saying if he is not a good man he will not last long, but even in a short time one or two towns may be pledged right up to their borrowing powers for works which are failures, and there is no recognised scale of remuneration. There is no doubt that in America there is a tendency to combine consulting work with contracting, of which Sir Alexander Kennedy, in his address to the Institution of Civil Engineers, says, "But now and then an attempt is made by honourable men, and in all honesty, to be contractors and consultants at the same time; every such attempt, so far as I know, has ended in failure, and I am sure that the combination is to be deprecated." 'Engineering' of November 9, 1906, commenting on Sir Alexander Kennedy's address, said, "It is, however, interesting to note that the plan objected to is apparently losing favour in America where the number of consultants in active and profitable practice is steadily increasing."

Before proceeding to the consideration of specific points where the status of engineers could be improved, I think it would be as well to glance at the constitution and action of the other learned or scientific professions. From the introduction to the Handbook of the Incorporated Law Society I gather the following facts: The Incorporated Law Society was preceded by the Inn of Court and the Society of Gentlemen Practisers founded in 1739. The Incorporated Law Society was founded in 1825 and got its first Charter in 1831. When it was founded, the only qualifications necessary to enable one to practise as a solicitor was to have been articled for a certain period without any test as to the knowledge gained during such articles. In 1833, the Society made its first effort to alter this by commencing a series of educational lectures, and in 1836 obtained a rule of Court making an examination necessary before admission as attorney and solicitor; in 1843, it obtained the Solicitors Act; in 1846, obtained the appointment of a Select Committee of the House of Commons to inquire into the state of legal education. By an Act in 1877 it was granted the full and independent control over solicitors' examinations. By the Act of 1888 the Discipline Committee is selected by the Master of the Rolls from its members of Council.

The work done by discipline committees would be impossible to go into in detail, but to show what it is intended to do I must again quote from the Handbook (page 24): "But to sum up in general terms a few of the leading subjects which have engaged the Society's attention, it may be said that when rules or regulations have come into force by which unnecessary obstruction or oppression has been laid upon them in carrying on the work of their profession; when the conduct of business has been impeded by delays capable of remedial measures; when claims unjust to solicitors have been asserted on behalf of the Bar; when a chance has presented itself of improving the ill-adapted system of solicitors' remuneration or of testing some unreasonable taxation; when advice has been needed by any member upon a *point of etiquette or practice*; under all these and many other circumstances the Council have laboured for the benefit of the general body."

In 1897, the House of Commons passed a resolution to defray out of the public funds a portion of the costs of the discipline committee, and each year a sum is included in the Civil Service estimates for this purpose. This appears to me to justify the statement made on page 23 of the Handbook, namely: "Every available opportunity has been taken of obtaining the introduction into current legislation of provisions furthering the just advancement and protecting the interests of solicitors as a class. The pages of the Statute Book bear witness to the fruit of these exertions."

By the courtesy of Mr. H. E. Allen, the London Registrar of the General Council of Medical Education and Registration, I obtained a copy of a series of resolutions passed by the General Council as the result of experience gained after having complaints brought against practitioners for misconduct. The first is, "As to the employment of unqualified persons as assistants or otherwise." This resolution points out that for a qualified man to in any way assist an unqualified man to practise and obtain the confidence of the public is "infamous conduct in a professional respect." The second is "As to association with unregistered dentists." The third, passed in 1899, is, "That the Council strongly disapproves of medical practitioners associating themselves with medical aid associations which systematically practise canvassing and advertising for the purpose of procuring patients." The fourth deals with the sale of poisons. The fifth deals with advertising and canvassing. This, the Council also state, constitutes in their opinion "infamous conduct in a professional respect," and renders them liable to be struck off the register. Mr. Allen also informs me that the conduct of a medical man is also governed by a number of unwritten conventions.

Having now reviewed the position held by engineers in four of the leading countries of the world—and the rules and regulations adopted in this country by one branch of the law and the medical profession—I now propose to devote our attention to what lessons we can learn from this review and what suggestions it gives rise to as to means whereby the status of the engineering profession can be improved in this country. I should like to suggest the following points for consideration, dividing them under two heads: (1) Those which apply to the profession and the public and control them equally, therefore requiring legislation; and (2) those which apply only to the internal regulation of the profession.

Under the first head I should place such questions as, Would it be wise and advisable for engineers to have a legal standard of qualification before they can be entrusted with the expenditure of public moneys or with works where the public safety is concerned? Questions dealing with the remuneration of engineers: What is an engineer's liability with regard to the works he designs, and how far he can or ought to put that liability on to the contractor? The ownership of drawings, calculations and designs.

Under the second head such questions as, Would it be desirable or otherwise to establish a discipline committee? Should the discipline committee be authorised to deal with the following? To what degree should it be professional to accept the contractor's designs and when the engineer ought to prepare his own? Under what conditions should a qualified engineer be entitled to advertise for work, or offer to prepare plans, etc., free in order to obtain work? should govern the regulations under which competitions are to be held.

Both in France and in Germany we find there is apparently no evidence of a standard of qualification required from the private consultant before he can be entrusted with the expenditure of public money; but this is only a delusion, because all the public expenditure is in the hands of the engineers of the Ponts et Chaussées in the one case, and in that of the engineers attached to the Ministry of Public Works in the other, so that in fact, as has been seen from the description of the training and the examinations, they have had to pass very definite restrictions, and very full qualifications are required before an engineer can be employed on works carried out at public expense. Whether it would be a good plan and in the interest of the public to have a Ministry of Public Works, supported by a staff of engineers here in England I do not propose to discuss, because I am now trying to suggest how to improve the position that exists, not to create a new one; but I should like to say that I think the consultant engineer of high standing such as we have in this country tends to very materially improve the trade of the country. They are retained and employed all over the world and they certainly are biassed in favour of the manufactures of their own country and the integrity of the manufacturers of it, and try to get the orders placed in it when possible. A further advantage in our English system is that when the Government or other authority requires advice on any special subject there are available a number of independent qualified men from whom they can select, whereas it would be a great expense to the nation to have them permanently in the pay of the Government or authority. In municipal work the difficulty of finding a man (apart from all question of technical education), who could possibly be expected to cope with the diversity of work which exists, both administrative and constructional, would be greater than it is if there were no consultants to call upon for assistance. Again the English system lends itself to specialising and competition, both conditions tending to advance the science of engineering.

In America the same position evidently exists that obtains in this country, and there also the feeling is evident that it ought to be altered. A topical discussion on engineering education at the American Society of Engineers was held last year, and Mr. Harold Bouton says the engineer's practices may be divided into four classes: (1) Frauds; (2) those depending on practical experience alone; (3) those who have prepared themselves, as well as circumstances, wisdom, and capacity permitted; (4) those who have taken technical courses under the instruction and supervision of others Then he gives eighteen disastrous results arising from this indiscriminate freedom of practice followed by ten causes of which I quote the first and tenth: (1) Entire lack of any regulation by Federal or State governments, or this

Society, of those who shall practise; (10) indifference of the profession at large to the deplorable condition.

Later on, he says that "Architects whose profession most nearly resemble engineering have examined the question. At present, it is said that the States of New Jersey, Illinois, and California require a licence for the practice of architecture. In New York State in 1901, a circular was sent to 995 architects asking for the expression of opinion for or against compulsory registration of architects. There were 520 replies, 493 in favour, 20 against, and 7 doubtful. The New York Chapter of the Institute of American Architects resolved that "No law can possibly be enforced at present which will take away from any individual the right to design and construct his own building."

Nothing would be more contrary to English practice and English methods than to restrict anybody's liberty to spend his money as he wished and on the advice of whom he wished, and I could never support any legislation which would do this; but the question of public money is quite another thing, and although other countries are younger than England as the homes of engineers' science, they have realised this point quicker. France and Germany have arrived at and have been putting in practice definite conclusions, and America is evidently advancing rapidly in the same direction. Many people may say, "how are such regulations and conditions to be put into practice?" but I am certain that given that the principle is accepted, the machinery to carry it into effect would not cause great difficulty. I do not for one moment suggest that there are not more questions to be solved in connection with the engineering profession than there are with both law and medicine, due to the fact that engineers are as much engineers when they are employed on the scientific questions of manufacture as when they are engaged on the design of structures. Any registration should in my opinion be equally open to all such engineers, and I feel sure that they in their employment would benefit by it—their position in relation to the other employés would be improved. The German training for the Staatsdienst is, of course, universal up to a certain point, and then it is divided into four sections: (1) Des Hochbaues (high works); (2) des Wasser und Strassenbaues (water and street works); (3) des Eisenbahnbaues (railways); (4) des Machinenbaues (machinery).

The register could be kept under these four or more or similar heads, and it would always be open to an engineer to qualify himself to practise under one or two or more heads. A minor advantage of this system is that parents, who are not engineers themselves, would have a definite line on which to educate their sons, if they wished to make engineers of them, and this, I think, would lead to the best class of men getting into the profession. It would also increase the esprit-de-corps among engineers, as one would always know that any registered man was one's equal, whereas, now, outside the Institution of Civil Engineers one has no guide whatsoever. There is no doubt that authorities frequently give work to incompetent men purely through ignorance, because to them an engineer is an engineer whether he drives an engine or designs bridges or waterworks. If there was some means by which they could, without trouble to themselves, be guided to the selection of a properly qualified man, such as by reference to a register, there is no doubt, in my mind, they would prefer it, and require no compulsion. The public health and purse would benefit. Compare the responsibilities and the duties of the medical officer of health and the borough engineer or surveyor. The respect and consideration the first gets in the public mind is due to the fact that he holds definite qualifications. The present system of using numberless letters as appendices to their names by such as hold no real qualifications is a distinct detriment to the profession and misleading to the public.

I have frequently been told by friends that a man must be a qualified engineer because he puts C.E. behind his name, believing this indicated qualifications such as M.D., and were utterly astonished when I told them there was no restriction whatsoever to their use. Every evidence that I can find and every argument I can suggest seem to clearly show that both the public and the engineer would benefit by a proper system of registration. That an unqualified man should not be entrusted with the erection of works to be used by the general public, the bad design of which might cause loss of life, is, in my opinion, self-evident; but although there is no standard of qualifications necessary this case does not frequently occur, owing to the fact that the greater number of these structures are in the hands of authorities, such as railway companies, whose engineers are all highly qualified men; but because the practice is good it does not prove that the system is good.

Now turning to the question of engineers' remuneration, this I consider an essential but very difficult point. The only charges so established that no discussion (if according to scale) can be raised are those of solicitors. The expense of keeping and rendering accounts on their system is excessive, being paid by the length of a letter, which, although only containing a few lines, and can therefore only be charged as a short letter, may have taken a very considerable amount of thought and reference before it could be written—is not a system or type of system which I could advocate. The architects' scale of charges is the nearest approach to what is required by engineers; but it has the great difficulty that it, to a great extent, assumes that all men are of the same calibre, and have had the same experience. The fact of putting the minimum daily fee at three guineas would make it very difficult for a senior in the profession who is fully justified in charging fifteen guineas to do so.

I have never heard a suggestion made, or can I conceive a scale which would apply to all cases sufficiently closely to be advocated; but although I do not think any scale can be adopted, I do consider that a very great deal might be done which would benefit the engineer by establishing a legal basis and system for his charges. For instance, it could be authoritatively laid down that a percentage is to be the basis of a charge when drawings have to be prepared from which works may be constructed, and at what stages proportion of such percentage becomes due. So that in the event of a dispute it could not be held by the judge (I believe this has been done; but I cannot find the reference now) that a percentage is not a proper method of charging, but that it ought to be *quantum meruit* based on time, etc. Further, such points as the length of a professional day. whether time occupied in travelling is to be paid for. Then it should be rendered legal for the Taxing Master to allow a reasonable amount for professional fees, and prevent injustices which frequently occur, such as the following: A property owner brought a case against a rich corporation, the corporation made no offer, and damages and costs were awarded against it; but the property owner was ruined, because to retain witnesses whose evidence would weigh against the evidence of those brought by the corporation, he had to pay very much beyond what the Taxing Master could allow. It frequently occurs that clients shrink from or avoid entering into an agreement, but lead engineers on step by step to do more and more work. When the work is done, the fee demanded is repudiated, and there is no remedy. The lawyer would of course say that he has his remedy at law, but the remedy is worse than the disease, because there is no legal basis on which to charge; the reputation of being litigious, whether rightly or wrongly gained, is very detrimental to his practice, and lastly, the cost both in time and money involved. If the client knew that the engineer was legally entitled to charge a certain percentage, or so much per day, and the only question which could arise would be the question of what per cent. or amount per day, this difficulty would be greatly modified.

To what extent an engineer is liable for the works he has designed, and to what extent he is liable for the efficient supervision by his subordinates are very difficult legal points, and I am afraid must remain so; but I think if some fairly clear statement of liability were laid down, it would be of great help to the engineer. To illustrate what I mean I will take the summing up of a case by Mr. Justice Bigham, reported on December 4, 1906. He says, "Any professional man engaged to do something in connection with his profession was bound to exercise reasonable care and reasonable skill. He was expected to have equipped himself with the necessary knowledge, and to add care and attention to the exercise of that knowledge. The degree of care and skill would depend on the circumstances of the case. The patient should not expect the same skill from a young practitioner of two and three and twenty as from an eminent surgeon. Again, if a surgeon was suddenly called in in the hurry of his practice, the degree of skill to be expected would not be the same as that which one might expect from a man who had plenty of time to think and decide upon a course of action. A surgeon who made a mistake of judgment was not necessarily liable, and they would have to beware of founding their verdict upon any mere error of judgment."

Here we have it clearly laid down that an error of judgment does not create liability. It is therefore necessary to prove something more than a mistake has been made, and I gather from this that liability can only result from negligence. On this rises a very difficult question as to what is negligence. We know that works dealing with large sums of money are nearly invariably given to the senior men whose age and experience are of great value to the undertakers, but whose very age renders it impossible for them to inspect the work themselves. Take, for example, could the average man of sixty-five go into a high air pressure in the construction of a tube, or go up a ladder 150 feet high? So that he is bound to depute this inspection. If he exercises care in the selection of his representative, can he be held liable, is a very important question.

How far an engineer or his clients can depute or ought to impose liability for his design on the contractor is another difficult question. If a contractor agrees to accept the liability, he is of course bound by his agreement, but how far it is in the interest of the profession for engineers to insert in their general condition of contract as a usual course that the contractor shall be responsible for the sufficiency of the design is a grave question for the profession to settle. If the client asks the contractor to guarantee the design it shows great want of faith in the engineer he has selected.

To engineers, the ownership of the drawings is not nearly so important a matter as it is to architects, because ordinarily they are only of use for the works for which they have been prepared, but notwithstanding this I think it is a matter which ought to be settled. I have heard solicitors argue that one is not legally entitled to retain a copy for future reference. If this is the true law, I think it ought to be altered, because, although one may not repeat the same design, the drawings for reference are frequently of great value.

Now dealing with the questions under the second head, which apply only to the internal regulation of the profession, we have seen the work done by the discipline committee of the Incorporated Law Society, and the resolutions passed by the general medical council, acting as a discipline committee. Clear definitions as to what the profession itself considers a proper professional course would no doubt be welcomed by all who wish by genuine work and merit to progress in their profession, and there is no doubt that a discipline committee, to whom points of etiquette could be referred, and in whom the members of the profession had confidence, would be a great influence for good.

The whole question of when an engineer should, in preference to preparing designs himself, apply to the contractor for designs, is a complicated one. No one would, I think, suggest that the independent professional engineer should, for instance, design either pumping engines or locomotives which may be required for works he is carrying out. On the other hand, there is no doubt that at times, rather than undertake the labour—and sometimes for want of knowledge—it does occur that the contractor practically provides the engineer with the design, when it would be more in the interest of the engineer's client, and of the profession, if he did this work himself. Another way in which this course injures the profession, is that clients ascertain what has occurred, and they naturally think, if the contractor supplies the design, why do I need an engineer? Further, the contractor also considers that, as he has to keep a technical staff, he does not see why an engineer should be paid for the work he, the contractor, does.

The next point to which I have referred under the second head, viz. Under what conditions should a qualified engineer be entitled to advertise for work, would at the first glance easily be answered by the words "under no conditions whatsoever." But when we examine the advertisement sheets of the engineering papers and find ourselves face to face with the names of some of the most honoured members of the Institution appearing as partners in firms who advertise, it makes one pause and ask, how are we to differentiate between members of the same profession who may, or may not, advertise and offer to prepare plans and estimates free? Competitions are a minor point in engineering work compared with architectural work, but at the same time there is no doubt that to control the method on which they are to be carried out, if allowed at all, would be an advantage.

I have endeavoured to give you, in as few words as possible, a review of the position of our profession in several countries of the world; to compare its constitution and rules with those of older professions, and to suggest for consideration various points where our organisation could be improved. In conclusion, I should like to urge, as the first and foremost necessity, that our profession, which deals with the life and health of the public by the thousand, should take steps to prevent the admission of all unqualified persons to its ranks, thereby increasing its usefulness and raising it higher in the esteem of the community at large.

March 4th, 1907.

JOSEPH WILLIAM WILSON, VICE-PRESIDENT, in the Chair.

THE CONNAUGHT BRIDGE, NATAL.*

BY EDWARD JOHN STEAD.

INTRODUCTORY.

IN preparing this paper the author's desire is to bring before the Society particulars of an accomplished work, in the hope that it may prove interesting to members generally as well as useful to those who may have similar works under their charge. This work is the Connaught Bridge, Natal, of which the author was resident engineer during construction. The bridge carries the north coast main road from Durban to Verulam and northwards to Zululand, over the Umgeni river at a point 4 miles distant from Durban and about 3 miles from the Indian Ocean. The new structure replaces an old low level timber bridge situated immediately on the upstream side, which was erected in 1868 by the Imperial Military Authorities. The area of the watershed of the Umgeni river above the bridge is 1660 square miles and the length of the river is 165 miles. The source of the river is near Spioen Kop and the Inhluzane Mountain, 6200 feet above sea level. There are two vertical falls in the river, Howick Falls and Albert Falls, together amounting to 380 feet. Allowing for these falls the average grade of the river is about 27 feet per mile, or 1 in 195.

RAINFALL.

From observations of rainfall during the last 10 years extraordinary rainfall seems to be confined to the coastal district, comprising about 130 square miles of the watershed. In that area 6 inches of rain fell in 3 hours on May 31, 1905, i.e. 2 inches per hour. Inland such heavy falls are not recorded within the last 10 years. The discharge at the bridge, due to an assumed maximum rainfall of 2 inches per hour, due to the coastal area of 130 square miles, would equal 10,000,000 cubic feet per minute, and it is possible that this discharge could occur in about 2 hours after the commencement of the rain. The whole watershed could be in operation in from 16 to 20 hours, assuming the velocity of the flooded river to be about 10 miles per hour. The discharge at the bridge due to an assumed maximum rainfall of 6 inches per 24 hours, or $\frac{1}{4}$ inch per hour, would equal 15,500,000 cubic feet per minute, making no allowance for loss by percolation.

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* The Bessemer Premium was awarded to the author for this paper.

The highest known flood level, that of 1856, is 27·10 feet above sea level datum, and the area of the cross section of the river up to that level is 15,500 square feet. At a velocity of 10 miles per hour, which was the velocity observed during an extraordinary flood in June 1905, the discharge at the bridge would be about 13,700,000 cubic feet per minute. The level of the bottom boom of girders is 29·47 feet above datum, but flood water could never reach higher than 28·77, when it would flow over the approach roads and expend itself over an enormously increased area.

General Description.

The bridge consists of twelve spans (Fig. 1, Plate I.), the total length between abutments being 922 feet 8 inches. Each end span is 74 feet 8 inches from the face of abutment to the centre of pier, and the other ten spans are 77 feet 4 inches from centre to centre of the piers, or 73 feet 4 inches in the clear. The girder bed level is 22·32 feet above winter level of river, and 2·37 feet above the highest known flood level. The abutment at the south or Durban end is built of concrete with a masonry facing, on a piled foundation, and the abutment at the north or Zululand end consists of a pair of cylinders, similar to the piers, with the embankment carried round them and faced with dry masonry pitching. Owing to the soft nature of the underlying strata it was not deemed advisable, nor was it reasonably practicable, to construct a concrete abutment on this side. Each pier is constructed of a pair of steel cylinders 25 feet 6 inches from centre to centre, sunk to a suitable foundation, and then filled up solid with concrete. The cylinders are 6 feet in diameter below the river bed and 4 feet diameter for the upper portion. The two cylinders are braced together to form one pier, and fitted with ornamental cast-iron caps.

The superstructure is of steel throughout. The main longitudinal girders are 7 feet 9 inches in height, of the N type, ten bays to each span, the four centre bays being counterbraced. Each span of main girders carries eleven cross girders 2 feet

6 inches deep, resting on and riveted to the lower booms. On the top of the cross girders corrugated flooring plates are riveted, the troughs of which are filled up with broken stone and asphalt. The whole floor is covered with a layer of broken stone and asphalt, upon which is the macadamised road surface. Footways 4 feet 4 inches wide are provided on each side of the bridge outside the main girders. The approach roads are of easy gradients, and 35 feet wide.

South Abutment.

The preliminary probings taken over the site of the south abutment indicated a bed of hard clay at a depth of 28 feet below ground level, upon which it was intended to commence concreting. However, in getting out the excavation difficulties were experienced in dealing with the water directly the level of the river bed was reached, i. e. 10 feet below ground level. The strata was so pervious that a very large quantity of water poured in. Two steam pumps, a 3-inch Pulsometer and a 5-inch centrifugal, were tried, but were found to be ineffective. An 8-inch centrifugal steam pumping plant was then utilised, and with that a depth of 15 feet from ground level was reached. Tube borings 3 inches diameter were then taken at several points in the excavation, and after passing through layers of sand and soft clay a hard blue gravel bottom was reached at a depth of 37 feet below ground level. The obvious difficulty, danger, and expense of having to carry an open excavation to such a depth through the unsatisfactory strata shown, caused a reconsideration of the design for this abutment, resulting in the adoption of piling.

There are seventy-five piles (Fig. 4, Plate I.) 12 inches by 12 inches pitch pine, the average length being 29 feet. The heads of the piles are braced together longitudinally and transversely with 12 inches by 6 inches pitch pine walings, and cross heads bolted with 1-inch diameter wrought-iron bolts. The piles were driven with a 1-ton hammer with an average drop of 7 feet. Two piling engines were worked at the same time, in one case a comparatively light guiding frame was utilised in conjunction with a 3-ton crane and a steam winch. The jib of the crane was stationed immediately over the head of the pile, the strain of raising the hammer being borne by the crane, the frame only serving to guide the pile. The wire-rope from the winch passed through a block at the foot of the crane, thence up the mast and to the jib and hammer. The other frame was of heavier construction, as no crane was used; the wire rope passed from the winch through a block at the foot of the ladder, thence over a pulley in the frame head. Both arrangements were effective and expeditious, though the lighter frame was the more easily moved from place to place, and the crane had only to be swung over each pile and stationed there by means of guy ropes. Piling was commenced on May 5, 1904, and completed on June 2, 1904, being 24 working days, giving practically three piles driven per day. The penetration of the piles at the last blows of the hammer varied from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch, with a drop of 7 feet. All the piles were cut off 1 foot above the level of the water, so as to allow the walings and cross heads to be fitted.

There was a depth of 5 feet of water in the excavation, and as the inflow was very heavy, pumping could not be carried on during any concrete work, so the concrete was placed under water by means of a bell-mouthed wooden shoot, 7 feet deep, made to go between the rows of piles. The shoot was hung on to the crane rope and lowered to the bottom of the excavation. The concrete was mixed in a Ransome drum mixer, tipped out on to a platform and left until it was in a semi-plastic state. This was done in order that the concrete should not be damaged in passing it through the water in the shoot. The shoot was filled up and constantly kept full so that the concrete was not tipped through water. By slightly lifting the shoot with the crane and rocking it a little, the concrete flowed out quietly and steadily and with a minimum disturbance of the cement. Concrete was filled in for the full width and length of the excavation and carried up to a height of 6 feet above the pile heads. Upon this foundation the abutments and wing walls were built of concrete, with rock-faced freestone masonry faces averaging 18 inches on the bed. A section of the abutment is shown in Fig. 5, Plate I. From the top of the concrete foundation to the level of the weep-holes, well-tempered clay puddle was placed with falls leading to the weep-holes, and above the puddle dry stone lining was carried to the top of the abutment. The girder bed-stones are of red Natal granite from the Alexandra Junction Granite quarries, which are situate some 30 miles south of Durban. The concrete throughout was composed of 6 parts of broken whinstone, 2-inch gauge, 3 parts of coarse sand from the Umgeni river bed at the bridge, and 1 part Portland cement.

The string courses, parapet walls, and pilasters, are all of rock-faced freestone masonry, obtained from the Mount Moreland quarries, 20 miles north of Durban. At the girder ends, small piers, 2 feet by 1 foot 3 inches, with caps, the underside of which are level with the tops of the girders, are designed to give a finished appearance, and between these small piers and the parapet walls are the entrances to the bridge footways. The caps on the small piers have white marble inscription tablets let into them, giving the name, dates, cost, etc., of the bridge.

The weight of the abutments and wing walls, etc., is 1500 tons, and, with the load of half a span imposed by the girders, and the live load on half a span, the total weight brought to bear on the foundation is 1628 tons. The base area of the concrete foundation is 1000 square feet, and the safe load for the material upon which it is built may be assumed at 0·75 of a ton per square foot—that is, 750 tons, leaving 878 tons to be carried by the piles, or $11\frac{1}{2}$ tons per pile. Taking the *Engineering News* formula, $L = \frac{2\,w\,h}{S + 1}$, where L equals safe load in tons, w = weight of hammer in tons, h = fall of hammer in feet, and S = penetration of pile in inches at the last blow, the safe load per pile works out at nearly 14 tons. The formula allows a factor of safety of 6.

CYLINDER PIERS.

The piers are composed of steel cylinders, 6 feet in diameter below river bed, and 4 feet diameter for the upper parts. The cylinders were made in 3 segments, with vertical angles $2\frac{1}{2}$ inches by $2\frac{1}{2}$ inches by $\frac{3}{8}$ inch, for riveting the segments together. The tops and bottoms are fitted with similar angles for bolting the successive lengths together with $\frac{3}{4}$-inch bolts, 6 inches pitch. The skin-plates are $\frac{3}{8}$ inch thick. The 6-feet diameter lengths are stiffened by a 5 inches by $2\frac{1}{2}$ inches by $\frac{3}{8}$ inch horizontal tee in the centre of the cylinder, and the 4 feet diameter lengths by a $2\frac{1}{2}$ inches by $2\frac{1}{2}$ inches by $\frac{3}{8}$ inch angle in a similar position. The bottom lengths of the 6-feet diameter cylinders have a $\frac{5}{8}$ inch by 12 inches cutting-plate riveted on to the outside of the skin plate, and these lengths are further stiffened by three 5 inches by $2\frac{1}{2}$ inches by $\frac{3}{8}$ inch tee vertically up the lower half. Details of the cylinders are shown in Fig. 6, Plate II. The top lengths of the 4-feet diameter cylinders are fitted with a $4\frac{1}{2}$ inches by $4\frac{1}{2}$ inches by $\frac{1}{2}$ inch angle outside, to which a moulded cast-iron cap is fixed by means of tap bolts. The rivets on the outside of all cylinders are countersunk. All the cylinders were shipped from England in three segments, and riveted together on the works.

The design provided for a 6 feet length of cylinder tapering from 6 feet to 4 feet diameter to form a connection between the different diameters of cylinders forming the pier, the level of the bottom of the taper pieces being about 2 feet below river bed level, and this level had to be adhered to. In the construction, however, it was found that it would be difficult and expensive to sink the 6 feet diameter cylinders to the exact levels to receive the taper pieces, or to adopt the only other alternative which appeared to be practicable, that is to obtain making-up pieces of cylinder, which would necessarily have to be obtained locally owing to the exact length required being indeterminable until the sinking of the cylinder was completed. In the first pier, when the cylinder was satisfactorily berthed on hard gravel, it was found that there was a space of 3 feet 4½ inches between the cylinder and the taper piece level, the top of the cylinder being 2 feet under water. At this stage the practical difficulty of using taper pieces had to be faced, and it was carefully considered by the engineers of the department. It was decided that it would not be advisable to attempt to sink the cylinders to the exact required depth to allow the taper piece to be fixed at its correct level. The level of the taper piece could not be altered owing to the position of the bracing of the piers, as will be seen by Fig. 2, Plate I. It was therefore decided that making-up pieces of the exact lengths should be obtained locally, and fixed on the cylinder, and upon these the taper pieces were set. The cost of making-up pieces obtained in the colony was nearly 100 per cent. higher than that of similar work imported from England. Time would not permit of the making-up pieces being made in England, and so the extra expense was unavoidable. Further, considerable difficulty was experienced in fixing the making-up pieces below water.

The experience gained in the first pier gave rise to the consideration of an alternative method of connecting the cylinders of different diameters, and the author proposed a form of telescopic joint, which was ultimately adopted on all other piers. In this design the 4 feet diameter cylinder is telescoped into the 6 feet diameter cylinder as much as is necessary to meet the levels, but not less in any case than 2 feet. The cylinders are filled solid from top to bottom with concrete, and in the concrete are embedded three railway rails about 10 feet long, as shown in Fig. 3, Plate I. An advantage of this joint is that any slight departure during sinking from the true position can be rectified when placing the lesser diameter cylinder, and perfect alignment assured. Practical demonstration of the strength of the joint was afforded during the heavy flood of 1st June, 1905, when the bridge was constructed only as far as pier No. 5. The flood brought down an enormous mass of debris which accumulated against the old bridge, causing it to be carried away. A large portion was dashed against pier No. 5, and turned broadside up against the pier. In that position it exerted a tremendous pressure on the pier, which showed not the least sign of failure.

SINKING CYLINDERS.

The staging and guides for sinking the cylinders are shown in Fig. 8, Plate II. The piles were 12 inches square and driven about 12 feet below river bed. A few inches above water level a set of 6 inches by 12 inches horizontal timbers were bolted to the piles, leaving a space of 2 inches between the faces and the outside of the cylinder in order that the cylinder might be controlled by wedges. The piles were left about 9 feet above water level and at the top a second set of horizontal timbers were fixed. Three lengths of cylinder were bolted together, the cutting edge being placed on the river bed, and carefully plumbed up every way, then sinking commenced. The sinking plant consisted of a 3-ton steam crane, mounted on a carriage and rails to travel longitudinally, and a grab. The crane was stationed on the centre line of the bridge and behind the pier, so as to work alternately at either cylinder. Two forms of grab were used, one being Butter's hemispherical grab, opening in three parts, and one oblong grab by Stothert and Pitt, opening in two parts. Both grabs did good work, but the latter was the better in clay. The former cut from the centre of the cylinder each time forming a "nest" and leaving a ring of clay all round the inside of the cylinder, thus impeding its descent. The oblong grab did not each time excavate from the same place, and consequently there was not the same liability for the cylinder hanging. As the coarse sand was excavated, the cylinder gradually sank without any load until depths from 15 to 25 feet were reached, and in some cases until the black clay material was entered. During the initial stages of sinking, great care was exercised in keeping the cylinder in correct position and perfectly plumb. It was found that after about 30 feet of sinking, if the cylinder was correct and plumb at that depth, it would remain so without any guides, so that the timbering was generally removed to allow greater facility in sinking. Some of the cylinders got slightly out of true position, chiefly by striking boulders. The correction for position was made in setting the 4-feet diameter cylinders.

When loading became necessary a special length of cylinder was bolted on. This length had brackets bolted to it, and upon the brackets two of the cross girders of the superstructure were bolted down, the top flanges of the girders being made level with the top of the cylinder, as shown in Fig. 7, Plate II. Upon the girders loading of railway rails, weighing 61 lb. per yard, was packed to weights required to start a downward movement. The amount of loading varied from a few tons to as much as 115 tons, and as a general rule, increased with the depth. The variations in the character and formation of the river bed and the underlying strata caused great differences in the amount of loading required. In Fig. 1, Plate I., the section indicates the main beds sunk through, but the formation is alluvial and very irregular. Thin layers of clay material and decayed vegetable matter were found in the sand bed, and thin layers and pockets of sand were sunk through in the black clay bed. In some piers heavy black mud and silt were sunk through. In cases where a cylinder could not be induced to descend under a fair load, small gelignite charges were dropped to the bottom and exploded, invariably having the desired effect. Excavation and loading were proceeded with by the one crane on each cylinder of a pier alternately.

The first pier sunk was pier No. 1, and the cylinders reached a bed of hard blue gravel at depths of 44 feet 3 inches and 49 feet 3 inches. In order to prove that the cylinders were not just resting on a ledge of gravel a borehole was put down about 20 feet north of the pier, and the gravel bed was found again at about the same depth. The deepest pier is No. 9, the cylinders there being 97 feet 9 inches and 103 feet 8 inches below river bed. The average depth of cylinders is 77 feet.

Preliminary probings had been taken over the site of each cylinder prior to the commencement of the construction of the bridge, and it was anticipated that a satisfactory foundation for the cylinders would be obtained on the clay bed at an average depth of 41 feet. When this bed was reached at pier No. 2, a test was made of its supporting power with very disappointing results. The bottom was cleaned and levelled by a diver, and a column lowered into the cylinder and stayed to the sides in such a manner that any downward movement was not impeded. The column was loaded and, with a weight equal to 2 tons per square foot of area of the base, sinkage commenced, and as the load was increased, sinking was continued until the column had gone down 5 feet into the clay, when the test was given up. Tube borings with 3-inch tubes were taken at every pier, and no practicable alternative was left but to sink the cylinders down to the white sea sand, upon which they now rest. It appears to the author that the portion of the Umgeni valley at the bridge, and for some distance inland, was at one time an arm of the sea, and that the strata overlying the white sand are all alluvial, gradually deposited by the river during a long period of years. It is interesting to note that a tooth of a hippopotamus was brought up from a cylinder when 70 feet deep.

The sinking of the cylinders was commenced at pier No. 1 on June 6, 1904, and a start was made at the cylinder abutment on the Zululand side on September 8, 1904, operations being carried on from both ends, pier No. 8 being the last to be sunk. The whole of the sinking was completed on October 6, 1905.

Surface Friction on Cylinders.

The resistance by friction on the outer skin of the cylinders was very small when sinking through the coarse sand bed, and in some cases depths of 30 feet were reached with no load at all, the weight of the cylinder (which at 30 feet would be 7 tons) and excavation from the interior by the grab being sufficient to cause descent. Neglecting altogether the first 15 feet, and assuming the friction to be all caused at a depth of from 15 to 30 feet, the area of cylinder exposed to frictional resistance would be 282 square feet, and the resistance is 55 lb. per square foot.

Upon entering the black clay bed, loading had always to be put on before any sinkage could be induced. In sinking pier No. 2 the first 30 feet was coarse sand, and the frictional resistance occurred as just described. When the cylinder was sunk to a depth of 44 feet, that is 14 feet into the clay, a load of 67½ tons was put on (including the weight of the cylinder), and with that load gelignite charges were required to start a downward movement. Taking the load supported by friction from the sand at 7 tons, there remains 60½ tons supported by the clay. The area exposed to the clay was 263 square feet, and the resistance works out at 515 lb. per square foot. In the same cylinder, when it was sunk a depth of 53 feet, that is, 23 feet into the clay bed, the load put on was 96 tons. Again, allowing 7 tons as supported by friction from the sand, there remain 89 tons supported by the area of 432 square feet in the clay, or 461 lb. per square foot.

In sinking pier No. 3, when the cylinder was sunk 69 feet, the load placed on was 115 tons. The coarse sand bed was 32 feet deep, therefore the cylinder was sunk 37 feet into the clay bed. Allowing 55 lb. per square inch for resistance by the sand at the depth from 15 to 32 feet, the weight supported is 8 tons (nearly), leaving 107 tons supported by the clay, or 345 lb. per square foot. In all the foregoing calculations the resistance encountered by the cutting edge is not taken into consideration. With the exception of the figures given for the frictional resistance by sand, it should be observed that in each of the other cases gelignite charges were required to start the descent of the cylinder, and the actual resistances would be slightly higher than the figures given. The irregularities in the resistances deduced at the different depths are accounted for by the irregular and peculiar formation of the river bed previously referred to.

For guidance in sinking cylinders on similar works the author would consider the frictional resistance by coarse sand at from 50 to 60 lb. per square foot during sinking by means of excavation from the interior, and by the alluvial silty clay at from 350 to 500 lb. per square foot. In cases where frictional resistance is to be relied on as a means of permanent support a much higher figure could be taken for resistance by sand at depths greater than 15 feet, as it is obvious that the continual excavation from the interior destroys to a very great extent the resistance to the descent of the cylinder. In alluvial strata similar to that described, the author would not allow as a permanent support a greater resistance than from 150 to 200 lb. per square foot.

Concrete Hearting and Completion of Piers.

As the sinking of each pier was completed, the steam crane was moved forward to start the next pier, its place being taken by a steam winch and crane, by which the concrete hearting was put into the cylinders. Concrete of 6 parts broken whinstone, 1½-inch gauge, 3 parts coarse sand, and 1 part Portland cement, was deposited by means of boxes, having doors in the bottom opening automatically when the box touched the bottom and the winch cable was slackened. The concrete was mixed in a Ransome drum mixer, driven by a 6 h.p. oil-engine, on the south bank of the river, loaded into the boxes and run on trucks along a service railway to the cylinder. Each box was picked up by the winch, and slowly lowered into the cylinder until the top of the box was an inch or two above the water, where it was held until all the air had bubbled out of the box, which was then slowly lowered into the cylinder. Upon touching the bottom, the box was gently lifted until the concrete was deposited, then hauled out, and returned to the mixer. About 25 to 30 feet of 6-feet diameter cylinder was concreted in a day.

The concrete was brought up to the level of the bottom of the reinforcing metals; these were placed and concreted in, and the 4-feet diameter cylinders, having been prepared in readiness, were dropped over them and set to the exact position and level, and the concrete brought up to the top of the metals. The bracing was all riveted together in one piece previously to being required and, one side of the pier being erected, the bracing was lifted on to blocks at the right level, and fixed to the cylinder with drifts and bolts. The other side of the pier was then brought up to the bracing, and the whole riveted up.

The 4-feet diameter cylinders were then concreted up to the top, and the girder bed plates set to their proper levels on the concrete.

TEST LOADS ON CYLINDERS.

Test loads were applied to two of the cylinders after they had been filled with concrete, and before the upper part of the pier was erected. The manner of carrying out the test at pier No. 10 is shown in Fig. 7, Plate II. Concrete hearting was deposited up to the level of the bottom of the reinforcing metals, and upon the concrete was constructed a timber staging to the top of the cylinder, and standing up 1 inch to allow for compression. At the first cylinder joint above water level, there was bolted on a length prepared with brackets and girders similar to that described for the sinking. The loading applied consisted of 166 tons of railway rails, and on the top of the rails was placed a cylinder filled with sand, the total load being 175 tons. The cylinder, concrete, etc., weighed 139 tons, making up a total load of 314 tons carried by the cylinder, and being equal to the maximum load which can be brought to bear on the cylinder. Loading was commenced over the centre of the cylinder, and gradually extended until the width shown in the illustration was reached. Between each row in height of rails there were placed 9-inch by 3-inch timbers to facilitate removal and fastening of sling chains. The loading was done by a steam winch and crane, and was commenced at 12.30 p.m. on May 19, 1905. The following table shows the progress of loading and results at the various stages:—

Date.	Time.	Load.	Total Sinkage.	Remarks.
1905.		Tons.	Inches.	
May 19	12.30 p.m.	Nil	Nil	Loading commenced.
„ „	5 p.m.	55	Nil	Work suspended for the night.
„ 20	7 a.m.	55	$\frac{3}{8}$	
„ „	1 p.m.	79	$\frac{3}{8}$	Saturday. Work suspended.
„ 21	9 a.m.	79	$\frac{3}{8}$	Sunday. No work done.
„ 22 . ..	7 a.m.	79	$\frac{3}{8}$	Monday. Work resumed.
„ „	9.30 a.m.	91	$\frac{5}{8}$	
„ „	11 a.m.	111	$\frac{7}{8}$	
„ „	12 noon	127	$1\frac{1}{8}$	
„ „	1 p.m	146	2	
„ „	2.45 p.m.	158	$2\frac{3}{8}$	
„ „	4.45 p.m.	175	$2\frac{3}{4}$	Loading completed.
„ 23	7 a.m.	175	$3\frac{1}{4}$	
„ „	2 p.m.	175	$3\frac{3}{8}$	
„ 24	7 a.m.	175	$3\frac{7}{8}$	
„ „ . ..	12 noon	175	$3\frac{7}{8}$	
July 15	—	Nil	$3\frac{7}{8}$	Check level. Loading removed.

The load was still on the cylinder when the flood of June 1, 1905, occurred, and the load stood until July 15, when check levels showed that no further sinkage had taken place, and the cylinder was considered to be stable. Neglecting surface friction, the load of 314 tons would exert a base pressure of 11 tons per square foot. Allowing for surface friction at 150 lb. per square foot, there would be a total resistance by surface friction of 91 tons leaving the base load as 8 tons per square foot.

Pier No. 12 on the Zululand side was tested in a similar manner. The depth of the cylinder was 73 feet 8 inches and the load applied was 150 tons. The weight of the cylinder and concrete was 122 tons, making the total load carried 272 tons. During the placing of the load there was only a very minute settlement. Loading was completed at 12 noon on March 10, 1905, and at 5 p.m. the sinkage was $\frac{3}{4}$ inch. At 7 a.m. on the following morning a further $\frac{1}{16}$ inch sinkage had taken place, making $\frac{13}{16}$ inch. The load remained on for 3 days and no further settlement took place. Neglecting surface friction, the base load was $9\frac{1}{2}$ tons per square foot. Allowing for surface frictional resistance at 150 lb. per square foot, and neglecting the first 15 feet in depth, the total load supported by friction works out at 74 tons, leaving the load on the base at 235 tons, or 7 tons per square foot.

SUPERSTRUCTURE.

A cross section of the superstructure is shown at Fig. 9, Plate III. The net length of main girders is 77 feet $2\frac{1}{2}$ inches, an expansion space of $1\frac{1}{2}$ inch being provided over each pier. The bed-plates are fixed on the concrete hearting by lewis bolts set in the concrete. One end of each span is bolted down to the bed-plates, the other end being free. The main girders were sent out in three lengths. An erecting stage on piles was constructed on the side of each span, and the main girders erected thereon by means of a steam travelling crane erected on the down stream side and standing at the centre of the span. The crane jib was 60 feet long, and could reach all over the span. No difficulties presented themselves in this portion of the work. A complete span weighs 70 tons, and about 12 days were taken to erect and bolt up a span ready for riveting. All the riveting was done by pneumatic power under a pressure of 100 lb. per square inch, and 5 hammers occupied about 14 days per span.

Upon the completion of the corrugated decking the whole floor was tarred. The troughs were then filled with broken stone and run in with hot liquid asphalt composed of coal tar pitch, anthracene oil, and sand. After the troughs were filled up, a coating of blue whinstone, 5 inches thick at the centre and cambered to 3 inches thick at the curb-plates, was laid down and also run with asphalt, and then steam-rolled with a 12-ton roller. Upon the asphalted stone was laid the macadamised roadway of blue whinstone, 4 inches thick at the centre and 3 inches thick at the sides, and steam rolled, blinded, watered, and again rolled and finished to a smooth surface, blue whinstone chippings being sprinkled on after the final rolling. The surface water drainage is carried off by outlets and piping from the curb plates; and the asphalted stone prevents percolation of water to the steelwork below.

The bridge footways are carried on brackets riveted to the main girders, and are composed of 9-inch by 3-inch creosoted deal planks carried on and spiked down to 6-inch by 4-inch pitch pine cross bearers bolted to the top flanges of brackets. In addition to the tube fencing, the outsides of each footway are protected by Cyclone wire fencing.

The embankments for approach roads are 40 feet wide, and are made of strippings from an adjoining quarry. The approach roads are 35 feet between the fences, and are macadamised. The embankment on the Zululand side extends round the front of the cylinder abutment, and is protected by dry masonry pitching, 15 inches thick.

FLOOD.

On the night of May 31, 1905, there was an extraordinary storm; the rainfall in Durban was 10½ inches in 15 hours, and at Pinetown, situate on the Palmeit spruit, which is a tributary of the Umgeni river, in the same period 15 inches fell. The Umgeni river rose 14 feet 1 inch, being at its height at 9 a.m. on June 1, and washed away the old low-level timber bridge. The new bridge was then erected as far as pier No. 5, and no part of the structure suffered any damage. Span 5 was erected on staging and bolted up ready for riveting; the erection stage was completely washed away, and the girders settled down until there was no camber. The span was, however, easily jacked up again to correct level. All the contractors' staging and machinery at pier No. 6 were washed away and deposited on an adjacent island, all mixed up with old bridge timbers and debris of all descriptions. A large quantity of timber was carried down to the Indian Ocean. Some of the cylinders lying on an island were rolled away down the river, and much other material was buried in the sand and debris. Pier No. 6 was at that time in course of sinking, and a part of the old bridge was washed up against it, and knocked the upper 18 feet right off by ripping the bolts out of the connecting angles. The flood caused a delay of 2 months in the execution of the works.

As soon as the flood subsided the P.W.D. commenced the erection of a temporary bridge to carry traffic until the completion of the Connaught Bridge. The district engineer, Mr. Arthur Head, assisted by the author, took charge of the work, and within 10 days a bridge some 500 feet long was available for traffic. As the temporary structure was not required for more than 6 months, it was of a somewhat rough and ready nature. On the sites of the trestles of the old bridge rough piers of stone were built to carry cross sleepers of Oregon pine 12 inches by 12 inches, and the spans were bridged with 35-feet baulks of Oregon pine 12 inches by 12 inches, seven baulks to a span. The baulks were decked over with 9-inch by 3-inch deals, and a macadam roadway 19 feet wide was made, with fences on each side. Where spans were too long for 35-feet timbers, new piers were put in, constructed of railway rail piles and 9-inch by 3-inch deal casing, inside which was packed the stone to carry the sleepers. In all, seventeen new spans were constructed, and the damaged spans at each end repaired and joined into the new work.

SETTING OUT WORKS, LEVELS, ETC.

A few notes on the methods adopted in setting out works, giving working levels, etc., may be of interest.

When the author took charge, he found centre line pegs, formed of railway rails set in concrete, on each bank of the river, which had been put in when the site was fixed, some time previously, and also bench marks, on each side of the river. These had been established by the surveyor of the site. As the centre line pegs were within the area of the works, the first thing done was to establish centre line points on the hillsides, on each bank of the river, at a considerable elevation, so as to be clear of any obstruction then existing, and in order to have an absolutely immovable and permanent centre point, for sighting to or from at each end of the bridge. The face line of the Durban end abutment was laid off and pegged. The bench marks were carefully checked, prior to doing any work from them. When the contractors' staging and plant were in position and working order, it was found that the exact centre line was often blocked, either by a crane or boiler, so a line, parallel to the centre line, and 4 feet at one side of it, was set out, and practically all the longitudinal measurements were made on this line.

As work commenced at both ends, some special care had to be taken in measuring off the total span of the bridge, and this was done by putting down a peg at the transverse centre line of each pier, and such intermediate pegs as the levels of the ground, or water, necessitated. Measurements were taken with a steel tape, from peg to peg, all across the river, and checked, and re-checked. When the closing span came to be checked before erection, it was found to be a slight fraction of an inch short, and was easily adjusted in the expansion space.

In setting out the piers, pegs were put in on the longitudinal line (known as the "four feet line"), about 20 feet north and south of the cylinders, so that a string line could always be run across, and another pair of pegs east and west on the transverse centre line. During sinking operations, another transverse line, 3 feet 3 inches north of the transverse centre line, was set off, and a string kept stretched across, so that any departure from correct position was at once detected and corrected. By making the dimension 3 feet 3 inches, the face of a 6-feet diameter cylinder had always to be 3 inches south of the string line. Constant check measurements were made from completed piers to those in progress, and after any small rise in the river, pegs were checked and verified. The main and permanent pegs were set in concrete. In the water, railway rails were driven down, and a punch mark put in the top. After the flood of June 1, 1905, all the cylinder pegs had to be reset out, as the river bed was entirely changed at that time, many pegs being either torn out, or completely buried.

The levels were easily taken from the bench marks, and set up wherever necessary. After each cylinder was founded and approved, the level of the ring joint nearest the water level was taken, and the depth of telescoping worked out and adjusted to meet each separate case The level of the cap angle, at the top of the 4-feet diameter top cylinder, was taken after the cylinder had been concreted, and the bedplate level set up whatever it might be above the cap angle.

The whole of the steelwork of the bridge was made by Messrs. Westwood and Co., of London, from the design of Mr. H. G. Humby, M.Inst.C.E., the Consulting Engineer to the Natal Government. The cost of the steelwork landed at Durban was 18,600*l*., and the total cost of the bridge, including land, compensations, surveys, etc., was 52,000*l*.

The bridge was erected for the Public Works Department, under contract, by Messrs. Smullins Bros. and Mansel, contractors, of Johannesburg and Durban. The amount of their contract, including abutments, earthworks, approach roads, and all incidental works, was 30,000*l*. Every credit is due to the contractors for the manner in which the erection was carried out, and for the earnest and satisfactory way in which they grappled with the difficulties caused by the disastrous flood in June 1905. The period occupied in erection was twenty-two months, namely, from March 1904 to January 1906.

In conclusion, the author desires to express his thanks to the Chief Engineer, P.W.D., Mr. J. F. E. Barnes, C.M.G., M.Inst.C E., for his permission to prepare this paper, and especially to Mr. Arthur Head, District Engineer, Durban, for much valuable advice and assistance in the carrying out of the author's duties on the works.

DISCUSSION.

The CHAIRMAN invited the meeting to pass a vote of thanks to Mr. Stead for his interesting paper; it was good of him to come from Natal and place his valuable experience before the Society. It was interesting to compare the way in which the upper and smaller portions of the pier cylinders were connected with the lower, with the way in which a somewhat similar process was carried out some forty or fifty years ago at Charing Cross bridge. The latter bridge had 14-feet diameter cylinders below water-level, and 10-feet diameter cylinders above. They were joined together with conical portions such as the author had shown in his illustrations. But there was a very considerable contrast between the two cases. In the Charing Cross bridge, the cylinders consisted of castings of considerable thickness, in which, he believed, six segments went to the circle; and the conical portion of that was a difficult job, involving the making and joining up of peculiar taper portions which connected the 14-feet diameter with the 10-feet diameter. In the present case the work consisted of a thin steel covering which would be easier to make and to join up; yet it seemed to him that the author was well advised in trying to get rid of that difficulty in the way that he had described in the paper. There were many points which, he thought, would come out in the discussion. Without saying more, he would ask the meeting to join in a very hearty vote of thanks to Mr. Stead.

The vote of thanks was carried by acclamation.

Mr. W. H. HOLTTUM said that the paper was of a kind which the Society was always very pleased to have, because it was a record of facts. The paper related to work that had been constructed, and not to work which it was proposed to construct, and about which engineers could have indulged considerably in their own theories. The work had been carried out most ingeniously. Some difficulties had occurred, and had been overcome, but they had been so well prepared for that taking the paper as a whole, he felt there was little left for discussion. There was, however, much to be learned from the work described in it.

He noticed that the cylinders went to a great depth and had their foundations in white sand and in gravel; although there had been some hope that they would be coming on to clay satisfactorily at little more than half their present depth. At home, and in London especially, solid London blue clay was appreciated for foundations; but discrimination was often wanting, during trial borings, in judging the nature of the clayey samples so obtained. In the river Thames, there had been vast excavations made for docks and other works, wrongly estimated for, upon such errors. Alluvial clayey silt, with traces of reeds, in place of solid clay had been discovered, which were no use at all for a foundation. The geological formation as described by the author, was within the large river bed of the Umgeni, and it was depth that the engineers relied upon for a foundation, also to the firmness of the sand, and to the surface friction on the cylinders.

There was a reference to concreting through a bell-mouthed shoot. Presumably that was very neatly performed; but why was the concrete left until it was in a semi-plastic state on the platform? He would like to know how long the concrete was left in that state, and whether the cement concrete used was like that in England which having once begun to set, was very much deteriorated if left for any length of time, and then further disturbed.

As to the use of explosives in the cylinders, he desired more detailed information. It would add to the value of the paper if particulars were given as to what charge was used in the bottom of the cylinders, and in what manner it was placed there. It was more or less alluvial silt that the cylinders were going through. He should also like to know whether the explosion caused general, inside and outside, disturbance of the silt or mud. The data as to the sinking of the cylinders was most valuable to the Society. He thought that it might become a standard practical reference for such purposes to members engaged in cylinder sinking.

With regard to the superstructure, no difficulties were encountered, and he had no criticisms to offer. It was some time since he had had anything to do with bridges of similar construction, although his earlier experiences had been in that direction. He would ask the author what governed the adoption of a width of 22 feet for the carriage way? Was it a definite necessity due to the nature of the local traffic in Natal?

He very much admired the aptitude of the author, and the district engineer, in the erection of the temporary bridge. He thanked the author for his valuable paper, and for the interesting description which he had given of the setting out of the work.

Mr. JOHN BLACKBOURN said that he had had, for a long period, a pretty good experience in all kinds of practical engineering in the Colonies, and he must say that he thought that the Society was indebted to the author for a valuable, practical paper. He—the speaker—was very much interested in that part relating to the setting out and the testing of the work. He would ask the author, what cement was used? Speaking as a colonial engineer "Portland cement" was a very vague term. It might be English Portland or German Portland, or anything else.

As to the temporary bridge, of course, that looked like smart work— ten days and 500 feet of bridge. He supposed that there was not the trouble with labourers that he had had in Australia, and he supposed that the author had no difficulty in getting plenty of labour. Of course, if they put on a very large number of men, they could do the work very quickly, and especially where the officials evidently knew what they were doing, and material was available. Very often a man who had successfully carried out work at home in England, might be totally unfit for carrying out work in the Colonies, the conditions being so different. The engineer had to accommodate himself very often to the material, and the labour on the ground, and that was sometimes a very difficult matter.

Mr. H. G. HUMBY said that it afforded him very great pleasure to meet Mr. Stead and listen to such a valuable paper, especially as Mr. Stead was a nominee of his own, three years ago when he joined the Natal Government staff.

In dealing with the subject of the paper, he regretted that he had to start by differing from the author in several of his remarks. He (Mr. Humby), as the author had told them, was responsible for the design of the bridge, and he had never yet been able to understand why a departure was made from the conical pieces connecting the 4-feet diameter top length of cylinder with the 6-feet diameter bottom length. When the data on which he was to work out the details of the bridge were given to him, they were of a very scant nature. Certain normal winter levels were given to him. Those meant low water levels in rivers which were practically dry in the winter season, and in flood during the summer. He worked to that normal level as what engineers would take in England, or in ordinary English practice, as low water mark corresponding to low water spring tide; and he arranged that the top of the bottom cylinder should be, at least, 12 inches above that level, so that there should be no difficulty whatever in connecting the conical piece with the six feet diameter cylinder. They were told, however—and that was the subject of a good deal of correspondence between himself and the government at the time—that there was some difficulty in sinking the 6-foot cylinders to the required level. He failed to understand even now why that should have been so. He could quite understand that they could not sink to an inch or half an inch, or even three inches, though, in strata such as those penetrated by the cylinders they had been sunk, he believed, to within three inches. And, moveover, compensating lengths were sent out so as to give an adjustable height to within twelve inches. He thought that if the department had taken the trouble to cable home about six weeks beforehand, they should require half a dozen more 12-inch compensating lengths, or two-foot compensating lengths, it would have been very easy to send them out in from two to three weeks from the receipt of the cable, and they would have been on the site before they were actually required.

But, apart from that, there was further compensation allowed for, in that the cylinders, which were of $\frac{3}{8}$-inch steel plates filled with concrete to within six inches of the top, had a bedstone resting on the concrete, and whatever final adjusting height was required could have been given by bedding the stone to the exact level.

He had had considerable experience in sinking cylinder foundations, and the use of explosives for that purpose seemed to him to be extremely dangerous. He had always opposed it, and the only occasion on which it was done was whilst he was away from the works, and contrary to his instructions. In that case only a small charge of dynamite was used. It was placed in about a twelve foot depth of water and the pressure brought on to the side of the cylinder was sufficient to rip up the whole of one joint, by carrying away the heads of all the bolts down that vertical joint, as might have been expected. They had not heard that there was an accident in the case mentioned by the author, and it appeared that there was none, at the same time, they did not know the condition of the bottom lengths of the cylinders; but even if they were not seriously damaged, the employment of explosives in sinking cylinders was a practice which he would not recommend.

He could not say why this length of span was adopted, beyond that it was in accordance with the order which came from the Colony by cable, asking for a bridge, a thousand feet long with so many spans; and that order was worked to as nearly as possible. If he had had a perfectly free hand, the bridge would have had 100-foot or 120-foot spans and not 77-foot spans, and he would have had 8-foot cylinders, that being in his opinion the most useful size, or he might say, the best standard size for colonial bridgework. He had had a large experience both of railway bridge and road bridge construction in the Colonies, and he was perfectly satisfied that there was no more economical span for either road or railway bridges than a span of from 100 to 120 feet. Whether it was a Warren girder, or an N-trussed girder did not matter.

It was not apparent to him why the north abutment or the abutment nearest to Durban was built of masonry. He thought that economy would have been attained by sinking cylinders in the same way as was done for the other piers and by surrounding them either with dry pitching, or masonry, or better still with a dwarf wall of concrete surrounding the foot of the embankment. All that expensive piling and pumping would have been dispensed with, against which the cost of sinking the cylinders would have been much less.

He had had some experience of South African rivers, and his opinion was that it was not absolutely necessary to have sunk the cylinders to the depth mentioned in the paper. In the case of the railway bridge, one on screw piles and situated only about 150 to 200 yards above the Connaught bridge, the screw blades of the columns were about 4 feet in diameter, and they were screwed down on an average only from 35 to 40 feet, and yet the bridge had been standing for over twenty years carrying the heaviest trains without any apparent sinkage. He thought that too much attention had been given to the sinking of the trial column in the cylinder which the author referred to. He did not think that that was the correct way of testing the foundation. If they had a small column within a cylinder and weighted it, it might be expected that the column would sink by displacing the material which had been more or less stirred up in the sinking of the cylinder; and to base their data on that was, he thought, wrong altogether.

It had been asked why the 22 feet width of roadway was adopted. The reason was that the bridge connected up several sugar plantations and mills, and the loaded mule carts conveying the sugar cane from one side of the river to the other, very often had an overhanging load of as much as 10 or 12 feet: and in order that the ordinary bullock-waggon traffic which was characteristic of that part in the country should be able to pass at the same time, it was decided to adopt 22 feet. He thought it advisable also to adapt a kerb which would keep the waggons off the girder work; that was the meaning of the peculiar kerb on each side of the roadway, and he believed it had been found very effective. It was a method which had been adopted on many bridges in India, and he had also adopted it on other bridges in South Africa with useful effect.

Mr. MAX AM ENDE said that, with regard to the most economical length of span there was a rule that the cost of the superstructure and the cost of the pier should be the same. The cost of the pier per unit of length was represented by a curve falling with increasing length of span, and the cost per unit of length of the superstructure was a rising curve. Where both curves intersected each other, there was the most economical span.

The most interesting point in the paper, to his mind, was the observation on the friction between the skin of the cylinders and the soil penetrated by them. Unusual prominence was given to this point by the author, but it seemed to him—the speaker—that the results found for the friction in the various strata, such as clay and sand were insufficient for setting up general data to be used in the design of a new bridge. It was not usual to rely on the friction for permanent resistance unless it was established by tests in each particular case. For clay a very high resistance had been recorded in the paper, but much depended on the exact nature of the clay, and he had reason to believe that in the sinking of the cylinders of the Albert Bridge over the Thames at Chelsea, the London clay offered next to no frictional resistance. In that case, however, the cutting edge of the cylinder projected about an inch outward, and that probably had a considerable influence on the reduction of the friction.

Mr. DRUITT HALPIN said that, the author had referred to the data on which the engineers started to get their maximum flood levels, and he said, "The highest known flood level, that of 1856, is 27·10 feet above sea level datum." Of course, that was the highest flood known, because in the new colony everything was dated from the flood. It was either before the flood or after the flood. That was time datum to which everything was referred.

In the general description the lengths of the girders were given at the abutments as 74 feet 8 inches, and the others were 77 feet 4 inches. He could not understand why that was, it seemed to him to be just about enough difference in length to throw the templets out, and to make the manufacture very awkward.

With regard to the way in which the taper pieces of the cylinders were made up, he certainly could not see any objection to it. One great objection which obviously existed to the taper pieces was the fact of not getting them properly packed with concrete in the haunches; and, if they did not get that, they would be in a very bad way. He certainly thought that with the class of labour the engineers were dealing with, the stopping short with the large cylinder and starting *de novo* with the small cylinder, where everything was level was a very good plan. The only thing to his mind open to comment, was the depth to which they had gone. The smaller cylinders had only been entered two feet inside the larger ones. He thought that a greater depth would be very desirable, as there were lateral stresses.

Regarding the use of explosives, he certainly thought that explosives should be used with the very greatest caution and the greatest delicacy. Engineers did not know what they were doing when they used explosives under the conditions referred to, and the damage that was done might not be found out until it was too late. To use explosives under such circumstances was a thing he should never dream of doing. He had to consider the case once very seriously in connection with an artesian well, and he was afraid to take the risk.

Mr. Blackbourn had referred to labour conditions. Forty or forty-five years ago labour conditions were very simple, as far as ordinary labour was concerned. As soon as the colonial engineer knew how much he had to spend, he wrote or sent a circular to everyone who was in charge of works to ask how many men each one wanted for the work, and, naturally, no one stinted himself, because he could have as much labour as he liked, and, if he did not take the full number of men applied for, it did not matter. The engineer got an order from the Secretary for colonial affairs, and the orders were sent to the Resident Magistrates, who sent orders to the various local native chiefs—instructing them to find a thousand men, or six hundred men, or two hundred men—and so on, and then the men were sent to whoever was in charge of the work. You simply gave notice three or four days before, and the men duly appeared, and there was no trouble. If there was any trouble, or if the men did anything wrong, it did not trouble the engineer. He simply wrote to the resident magistrate, and the magistrate notified the native police, who took it in hand with the native chiefs. The labourers worked for ten shillings a month all the year round, and they got three pounds of Indian corn a day, as well as three pounds of beef a month. The arrangements in connection with all labour were very simple.

Mr. E. I. GROVE asked how the boulders were dealt with, if they were found under the edge of the cylinder. Was gelignite used to clear them?

Mr. F. G. BLOYD said that reference had already been made to the kerb plate roadway, and the first thing that struck him when he saw the general design of the bridge and the cross section (Fig. 9) was the shape of that plate. Mr. Humby said that kerb plates of that form were extensively used in India and in Africa. He must confess, however, that he had never seen one of them in English practice. He had been dealing that day with a bridge carrying a road over a railway, where the metalling was taken right up to the inside face of the webs of the main girders. In such cases when the web was repaired, it was a most difficult matter to get at the lower part of the web or the lower inside angle irons. The whole of the metalling would have to be first removed from the sides of the bridge. In the kerb plate shown in the drawings, a great improvement had, he thought, been effected. The water from the roadway was taken down a small pipe as seen in the plan, clear of the girder work altogether, and the space inside the kerb plate would be very useful if gas or water pipes or cables were ever required to be laid over the bridge, although he did not suppose that it would be necessary to take pipes over that bridge. It would be seen that the footway was built up on cantilever brackets. To his mind the footway did not seem of the same permanent character as the rest of the bridge. Perhaps, the author would tell them that the cost of some better description of timber than ordinary creosoted deal planks was prohibitive in South Africa. But he (Mr. Bloyd) thought, that Jarrah timber, or one of the other hard-wood timbers might have been employed, and that there would have been far less risk of fire with it than with ordinary creosoted deal.

He would ask the author whether there was any objection to attaching the cross girders to the bottom flange of the main girders, cantilevering them out and then building up the footpaths on those girders. He knew that in general practice it was not thought very desirable to suspend the cross girders from the main girders, it being considered much safer to rest the former on the bottom flange of the latter, but in the present case they seemed to have got a good broad bottom flange, and he thought the cross girders might have been suspended, which would have had the advantage of lowering the level of the roadway, thereby affording protection to the traffic, by increasing the height of the side screens.

He would like the author to say if some better description of timber could not have been employed for the footway, in order to effect a saving in the cost of maintenance. Of course, first cost was very often an important point with the engineer when constructing a bridge. But the engineer who would have to maintain the footway in the future would, he thought, have to incur a rather heavy expense.

Mr. Bernard J. Belsher said that he had listened to a very useful paper. He noticed that the concrete was composed of ingredients in the proportion of 9 to 1. It struck him that that was a rather unusual proportion. It was unusual in this country to have only one volume of cement to six of broken stone and three of sand. Suppose that in time, a cylinder corroded away below the low water level, the structure would then be merely dependent upon the strength of the concrete. No doubt if good concrete was used it would be strong enough to carry the superstructure, and the frictional resistance of the ground against the concrete would be pretty much the same as against the steel. He thought that under the circumstances, it would have been better, to have made the concrete stronger. However, he did not know what the Portland cement was supposed to break at. They could get Portland cement to break up to a 1000 lb. a square inch, but he believed that it was usual to specify only 400 lb.

With regard to the method adopted of connecting the two cylinders together, it seemed to him that the three vertical rails were really altogether unnecessary at that point, because they were at the bottom of the 4-foot cylinder. In other words they were at the bottom of a column and just above the ground level and the bending moment would be zero at the bottom of a column. The only thing to fear at all was a horizontal shearing through the column at the joint. He thought that it was practically impossible for the column to shear off (although, of course, they knew that there was a great force striking against it when floods took place), because the bottom of the top cylinder was let into the top of the lower cylinder at the point referred to, and both were filled and surrounded with concrete, so that it would be impossible for the top cylinder to move.

He was rather surprised that the footway flooring was made of planks of creosoted deal and not steel chequered plates, or something more durable than wood. He thought it was perhaps due to the fact that steel would be rather difficult and expensive to paint from time to time, on the underside, and it would otherwise corrode.

He also noticed that the piles were not only bedded a considerable distance into the concrete under the abutment as shown in Fig. 5, but they were also braced together. It seemed to him that there was an unnecessary length of pile in the concrete, for it would have been utterly impossible for the piles to have come apart with all that enormous mass of concrete around them: and they might either have been driven further into the ground, or reduced in depth, or shorter piles might have been used.

As to the kerbing, it seemed to him an excellent idea for keeping the road metalling and vehicles away from the main girders, and thereby preventing them from rusting as they otherwise would do. At the same time he considered that it should have been flat, or have had a flat gradient on the top instead of being circular, so that anyone might stand thereon when crossing the bridge, if desirous of getting out of the way of a vehicle. It struck him on first looking at the design, that the object of this kerbing was to make pipeways across the bridge, but on second thoughts he surmised that they did not have pipe-mains in that part of Natal, and that the only mains would consist of overhead wires.

Mr. PERRY F. NURSEY said that he had never had the honour of erecting a bridge, but he had had the questionable honour of demolishing two. One was a railway bridge over a road at Quenast, in Belgium, which he took down in 1872, and the other was the Mustard Lane Bridge over the Great Western Railway in the Sonning cutting, near Reading, which was removed in 1891, in connection with the Didcot widening of that line. It was one of Brunel's three-span bridges. He took down those two bridges by blowing them up. Hence, he had an explosive interest in the paper, but he had been to some extent anticipated by Mr. Holttum and Mr. Halpin in the questions which he had intended to ask. It appeared to him that the operation described by the author was, structurally, a dangerous one at the best, and he should like to know the amount of charge used, and whether a boring was made in the soil in which the charge was deposited, or whether it was merely dropped into the cylinder and exploded by a fuse, or by electricity, and whether there was a head of water in the cylinder which would form a tamping. If there was nothing to concentrate the local action of the gelignite, the structural risk would not be so imminent, although it would be present. If there was a head of water, the danger to the cylinder might be very considerable, according to the charge used.

Some seventeen years ago, in 1890 in fact, he cleared away the bases of four cast-iron cylinders in the bed of the Thames at the Tunnel Wharf, Wapping. There had been a steam ferry between that wharf and Rotherhithe, and the landing stage at Wapping was carried on columns; and, when it was demolished —for the ferry proved a failure—the columns were taken down by hauling on from the top, and it was hoped that they would snap off level with the bed of the Thames. Four of them, however, did not snap off level, but broke a foot or two above the bed. The Conservators of the Thames, therefore, required the snags to be cleared away, as they constituted a risk to navigation. He undertook to clear them, and he did clear them. They were 4-foot cylinders with concrete filling. He bored a hole in the concrete at low water, and put in a charge of dynamite, using a cap and a time-fuse. He fired his shots with about 14 feet head of water. In every case he was perfectly successful; the bases of the columns being demolished. He had to take great care, and to use moderate charges, because of the proximity of the crown of the Thames Tunnel. But notwithstanding the small charges, they did great execution, and it occurred to him that it would be interesting to know the conditions under which the explosives were used in the cylinders of the Connaught Bridge.

Mr. H. G. Humby said that he should like to add a remark in answer to a question put by one of the speakers, as to the reason why the kerb was made so steep, and had not a flat resting-place on the top. It was purposely designed curved so as to prevent mules, when they shied across the bridge, mounting the kerb and becoming entangled in the lattice-work of the main girders.

Mr. S. A. Stevens asked the author whether in South Africa they were used to extremely heavy traction engine traffic such as existed in England, and whether the bridge was sufficiently strong to bear two or three such engines with their contingent loads. Nothing was said in the paper about the load the bridge was designed to bear.

Mr. E. J. Stead in replying to the discussion, said that as to the plastic concrete in the abutment, to which Mr. Holttum had referred, it was turned out and left a quarter of an hour on the boards so that the cement got a grip of the stone, and was not washed off. They had experimented with it in putting the concrete fresh from the drum into the water, and it was found that, in the bottom of the tube, there was simply a collection of stones and sand, with the cement floating on the top; but when they tried it the other way, leaving it a quarter of an hour on the boards the result was quite satisfactory. They got concrete and not a collection of stones. Mr. Holttum and other speakers had inquired as to the explosives. The explosive used was gelignite. The charge was generally half a cartridge, and it was exploded in the bottom of the cylinder. The cylinders were loaded up until they had their full load on and then the half cartridge of gelignite was dropped in through the top of the cylinder. It fell down through the water and was exploded by a time fuse when it reached the bottom. There was no accident, and the result was satisfactory. Of course, the setting up of a vibration or concussion in the cylinder to produce a sinkage was not new. It had been adopted in India.

The cement used in the concrete was a British cement, made by Knight, Bevan and Sturge (Pyramid Brand). He did not know exactly the locality from which it came.

In reference to the temporary bridge erected after the flood, a question had been asked by Mr. Blackbourn about the labour employed. They had seven white men and sixty natives. Roughly speaking—the bridge was built from both ends, the District Engineer was at one end, and he (Mr. Stead) at the other, and they worked towards the middle.

Mr. Humby had made some remarks about the telescopic joint, or, as he called it in his correspondence, the "candlestick joint," which he (Mr. Stead) thought was an excellent name for it. The first thing that struck him about the taper pieces was that the bottom of them was below the water level. Mr. Humby had told them that he designed the bridge with the taper level 1 foot above the water level. Of course, if it had been so, and had come out to that level, there would not have been the slightest difficulty in using it; but the actual low-water level which they got was 2 feet above the level of bottom of the taper piece. It did not need much experience to show that there was a difficulty in fixing work like that. He quite agreed with Mr. Humby that, if they could have got 12 inches above the water level, the taper length would have made a very good joint. Mr. Humby had asked why they did not cable home for the compensating length? The answer was that they had not time to do so.

Mr. Humby asked why they made a masonry abutment at the Durban end? He (Mr. Stead) could not give the reason. The bridge was designed before he got out there, and the drawings handed to him showed the abutment. He had no idea why it was so designed, but as it was in the borough of Durban, the most important town in the Colony, that probably had something to do with it. He thought Mr. Humby was under a misapprehension as to the condition of the bottom of the cylinder at Pier 2, when he made his remark about the testing of the column. The test was not made on clay in the cylinder. The clay was below the bottom of the cutting edge which the bottom rested on. It was only a rough test, but it satisfied him and the other engineers, that the clay would not do to found the cylinders on.

Mr. Halpin had mentioned the possible difficulty of manufacturing the girders, owing to the end spans not being the same. But, of course, the girders were of exactly the same length in each case. There was 77 feet 4 inches distance from centre to centre of the piers; and 74 feet 8 inches distance from the centre of the pier to the face of the abutment, the net length of girders being 77 feet 2½ inches.

He had been asked by Mr. Grove how boulders were dealt with. He might say that they had only very few boulders, and they were at a shallow depth. They were removed by the diver.

A question had been asked by Mr. Bloyd as to the timber used for the footways. Creosoted deal answered very satisfactorily for light foot traffic; and it was very easily repaired if any planks got out of order. Jarrah wood was very expensive, and the cost was practically prohibitive.

Mr. Belsher had criticised the concrete. He (Mr. Stead) might say that 6 of aggregate to 1 of matrix was a splendid concrete. The cement was specified in the specification to break at not less than 400 lb. to the square inch.

Mr. Stevens had asked what the load was, and what the bridge was allowed to carry. The live road was 1¼ ton per foot forward. The bridge would carry traction engines over it.

Mr. P. F. Nursey: I think you said that the charge was half an ordinary cartridge of gelignite. That would be about one ounce, and would give a fair shaking.

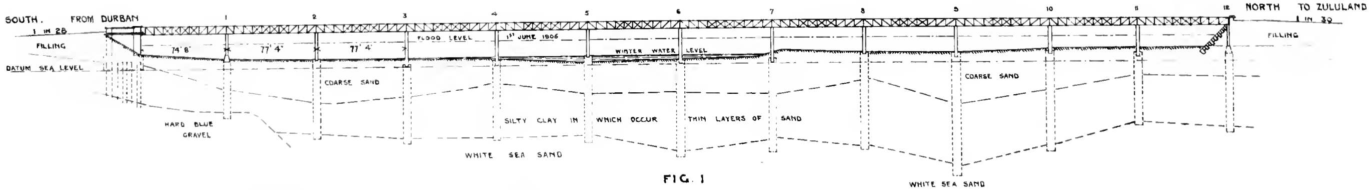

SOUTH.
FROM DURBAN
1 IN 28
FILLING
DATUM SEA LEVEL
1
2
3
4
5
6
7
8
9
10
11
12
74' 8"
77' 4"
77' 4"
FLOOD LEVEL
1ST JUNE 1906
WINTER WATER LEVEL
COARSE SAND
HARD BLUE GRAVEL
SILTY CLAY IN WHICH OCCUR THIN LAYERS OF SAND
WHITE SEA SAND
COARSE SAND
WHITE SEA SAND
NORTH TO ZULULAND
1 IN 30
FILLING

FIG. 1

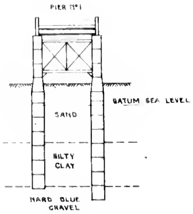

PIER No 1
DATUM SEA LEVEL
SAND
SILTY CLAY
HARD BLUE GRAVEL

FIG. 2

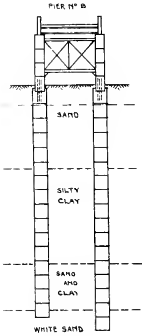

PIER No 8
SAND
SILTY CLAY
SAND AND CLAY
WHITE SAND

FIG. 3

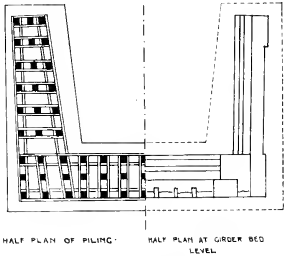

HALF PLAN OF PILING.
HALF PLAN AT GIRDER BED LEVEL

FIG. 4

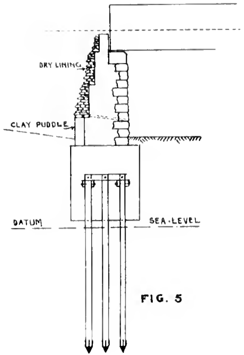

DRY LINING
CLAY PUDDLE
DATUM
SEA-LEVEL

FIG. 5

SCALES:
FIG. 1. 1 INCH = 80 FEET.
FIG. 2 & FIG. 3. 1 INCH = 40 FEET.
FIG. 4 & FIG. 5. 1 INCH = 16 FEET.

C F KELL & SON, PHOTO LITHO 2 & 3 TOTHILL STREET WESTMINSTER

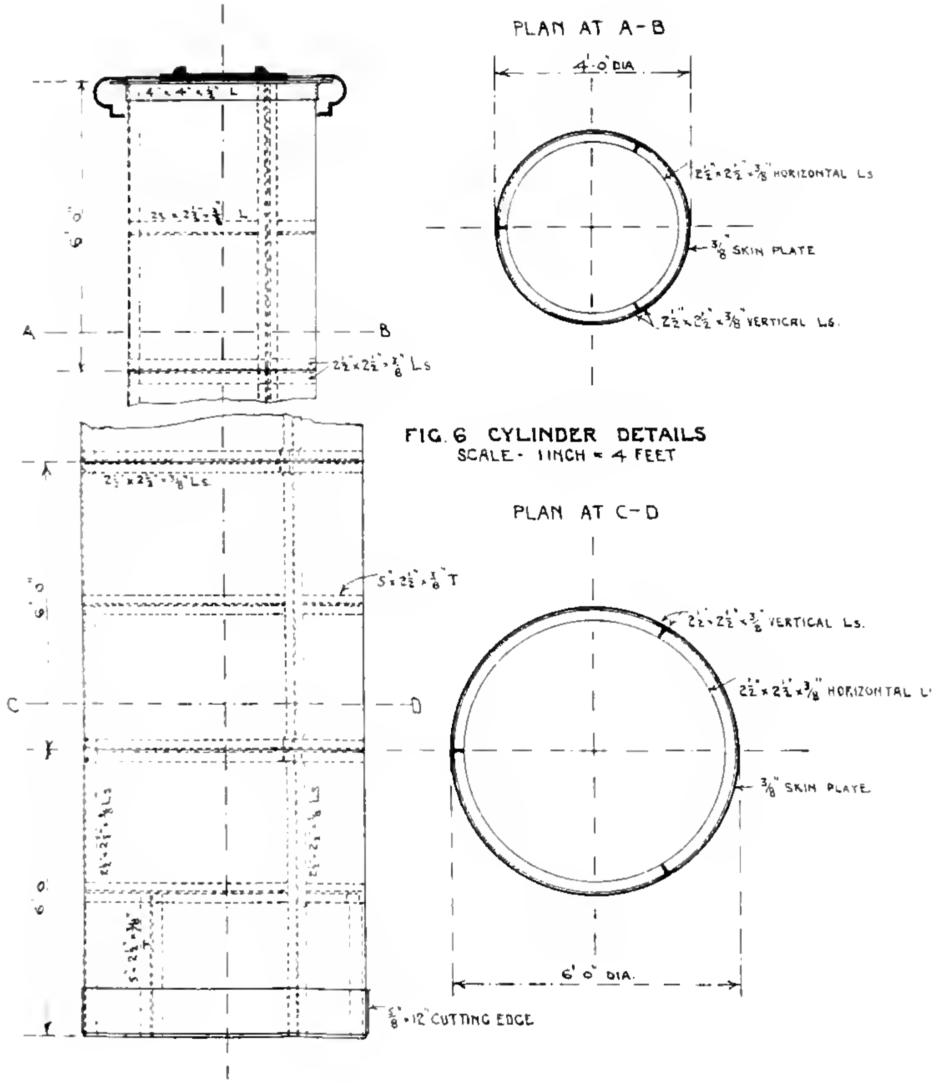

4"×4"×½" L
6' 0"
2½"×2½"×⅜" L
A
B
2½"×2½"×⅜" Ls
PLAN AT A-B
4' 0" DIA.
2½"×2½"×⅜" HORIZONTAL Ls
⅜" SKIN PLATE
2½"×2½"×⅜" VERTICAL Ls.
2½"×2½"×⅜" Ls
5"×2½"×⅜" T
6' 0"
C
D
2½"×2½"×⅜" Ls
6' 0"
5"×2½"×⅜" T
⅝"×12" CUTTING EDGE
PLAN AT C-D
2½"×2½"×⅜" VERTICAL Ls.
2½"×2½"×⅜" HORIZONTAL L
⅜" SKIN PLATE
6' 0" DIA.

FIG. 6 CYLINDER DETAILS
SCALE - 1 INCH = 4 FEET

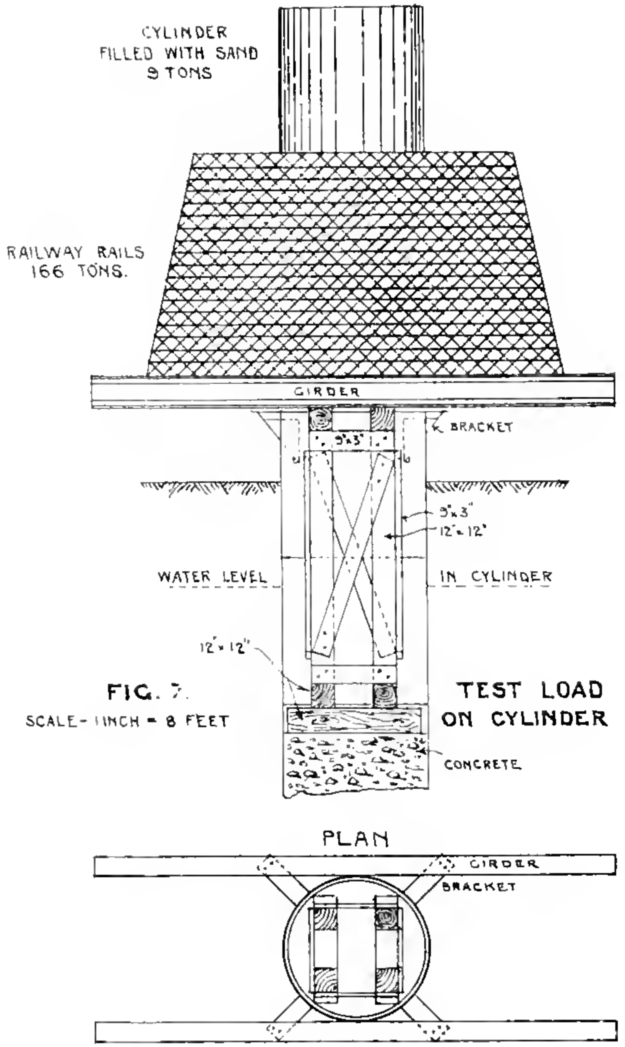

CYLINDER
FILLED WITH SAND
9 TONS
RAILWAY RAILS
166 TONS.
GIRDER
BRACKET
9"×3"
9"×3"
12"×12"
WATER LEVEL
IN CYLINDER
12"×12"
CONCRETE
PLAN
GIRDER
BRACKET

FIG. 7.
SCALE - 1 INCH = 8 FEET

TEST LOAD ON CYLINDER

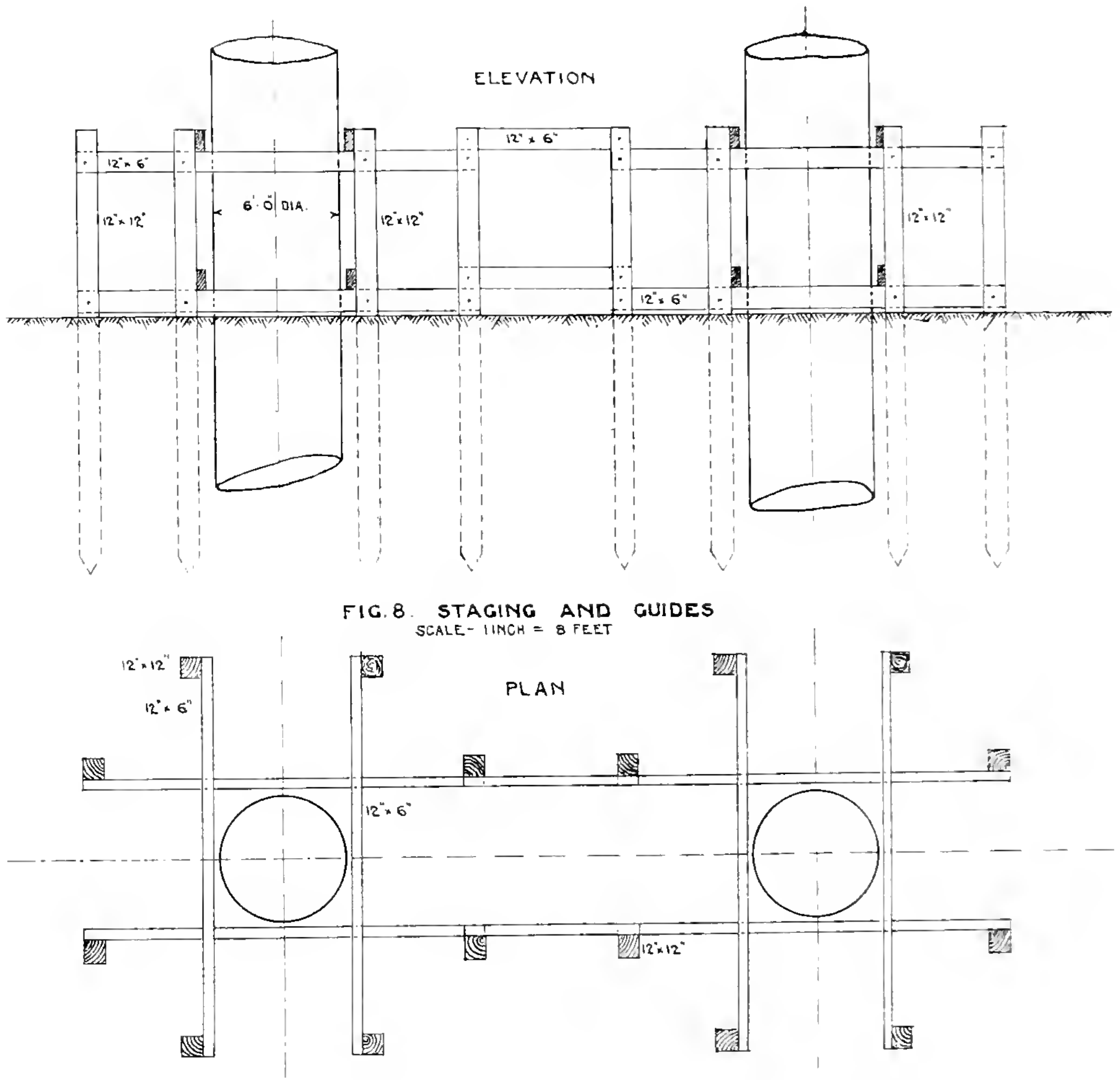
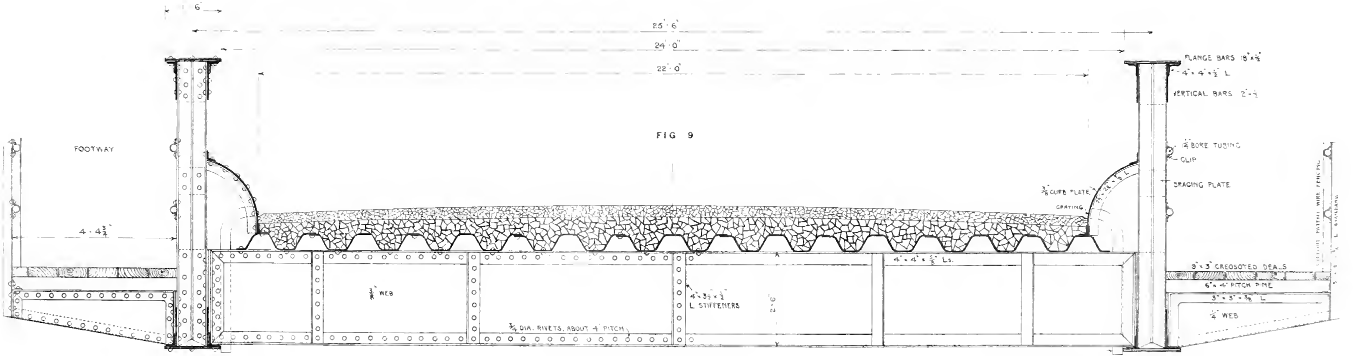

ELEVATION
12"×6"
12"×6"
12"×12"
6' 0" DIA.
12"×12"
12"×12"
12"×6"
PLAN
12"×12"
12"×6"
12"×6"
12"×12"

FIG. 8. STAGING AND GUIDES
SCALE - 1 INCH = 8 FEET

[illegible] PHOTO-LITHO 2 & 3 TOTHILL STREET WESTMINSTER

FIG 9


6"
25'·6"
24'·0"
22'·0"
FOOTWAY
4'·4¾"
FLANGE BARS 18" × ½"
4" × 4" × ½" L
VERTICAL BARS 2" × ½"
1¼" BORE TUBING
CLIP
BRACING PLATE
⅜" CURB PLATE
GRATING
3½" × 2½" × ⅜" L
9" × 3" CREOSOTED DEALS
6" × 4" PITCH PINE
3" × 3" × ⅜" L
¼" WEB
4" × 4" × ⅜" Ls.
⅜" WEB
4" × 3½" × ½" L STIFFENERS
2'·6"
¾ DIA. RIVETS, ABOUT 4" PITCH
SURFACE WATER DRAINAGE PIPE FROM ROADWAY

CROSS SECTION OF SUPERSTRUCTURE
SCALE 1 INCH = 2 FEET

April 8th, 1907.

JOSEPH W. WILSON, VICE-PRESIDENT, IN THE CHAIR.

THE RENARD AND SOURCOUF ROAD-TRAIN SYSTEM.

By BENJAMIN H. THWAITE AND RICHARD F. THORP.

INTRODUCTION.

ONE of the most serious problems of the present day is the restoration of the equilibrium between the city and rural populations, the cry "back to the land" being heard on all sides. Whilst farmers are deploring a scarcity of hands, owing to the immigration of labourers to towns, the unemployed crowd the streets of our cities. Any system, therefore, which will tend towards the decentralisation of the masses, deserves serious consideration. One remedy that should help to bring back prosperity to the farmer, and induce the labourer to stay with him, would be a more economical, rapid, and convenient method of road transport.

It is generally admitted—and this opinion created the Light Railways Act—that if the farmer could secure a rapid, safe, and cheap method of transport, it would transform his prospects. This opinion led the authors to examine the possibilities of the latest attempt to solve the problem of mechanical road transport, and to embody the results of their investigations in this paper.

Many of our best agricultural areas are far removed from railways owing to the opposition of landlords to the railway in the pioneer days, whilst the cost of a light railway would be too great. The history of the evolution of modern road motor transport systems provides many examples of the obstacles that are thrown in the way of the progress of innovations on established systems in this country. The country, is, however, becoming day by day more liberal in its attitude towards new inventions.

EARLY MECHANICAL ROAD TRANSPORT.

In a paper read before this Society by one of the present authors the policy of canal suppression adopted by railway companies in the early days of railways was explained. Canals, however, were not the only methods of transport that suffered by the advent of the locomotive. There had been many attempts before Stephenson's railway successes, to solve the problem of applying James Watt's invention to the propulsion of road vehicles, but no real progress appears to have been made until about the year 1829, when Gurney and Handcock entered the lists, and Handcock may fairly be considered to be the creator of the steam road transport system. Fig. 1, which shows Handcock's motor 'bus, or coach, gives an idea of the comparative perfection which the system had reached before the date of Stephenson's success.

Dance was the first to organise a regular service of motor coaches. He established the first service in 1831, between Cheltenham and Gloucester. In the same year, Napier constructed a belt-driven steam carriage, which proved a practical success. A service of Handcock's steam motor coaches commenced to run between Paddington and the City in 1834, following which, in the forties, motor-coaches commenced to run between Stratford and Paddington. This is the last of the services established known to the authors. The railway boom came, and all rival transporting systems were forgotten. Nevertheless, many developments in detail followed the early runs of Handcock's motor coaches. The advantages of securing a thoroughly reliable resilient tyre were appreciated. Resilient indiarubber solid tyres were applied, and even the differential gear was known.

THE RED FLAG ACT.

Railway influence, even in Parliament, became very powerful, and no rival mechanical road transport system would have had any chance against it. An Act was introduced into Parliament in 1865, the object being to close the British highways against any system of mechanical transport, other than the traction engine. This Act was known as the Red Flag Act. The drastic character of this Act, will be understood from the following provision which it contained.

"No mechanical transport system travelling on a public road must be permitted in towns or villages to exceed a speed of more than 2 miles an hour, and on other roads 4 miles. At least three persons must be allotted to drive or control the mechanically propelled vehicle, and if any additional vehicle trailed, a fourth man must be provided."

Moreover, one of the staff had to precede the vehicle on foot by at least 20 yards, and carry a red flag, and the mechanically propelled vehicle had to be immediately stopped when any person with a horse or a carriage drawn by a horse, raised his hand. It is impossible to conceive an Act more likely to suppress ingenuity in the direction of applying the resources of mechanical science for road transport services.

A Royal Commission.

This Act was allowed to remain undisturbed for many years, but in the year 1873 a Royal Commission was appointed to consider the desirability of providing facilities for the introduction of mechanical road systems of transport. The commission met, and decided to recommend, "that self-contained locomotive coaches, not exceeding 6 tons, noiseless and non-smoke producing, be declared to be light vehicles, and that they be permitted to travel at the ordinary speed of horse-drawn vehicles, and be subject to the same restrictions as apply to such vehicles." This, like many other royal commissions, was probably a parliamentary method of shelving an awkward subject, because the government did not adopt the recommendations.

Continental Progress.

The untrammelled efforts of invention in Germany and France, however, were producing remarkable developments in mechanical road transport. Thanks to the genius of Napoleon, and to his road-making propensities, and to the French engineers of bridges and roads, and thanks also to the general encouragement given to the automobile industry in France, inventors made rapid progress in perfecting mechanical systems of road transport. But it is only fair to our own countrymen to note that British engineers can claim a right to a share in the honour of participating in the pioneer work of effecting mechanical transport on roads. Indeed, the progress made by the early pioneers in applying Watt's steam engine for vehicular service, considering the time, is most remarkable. It is said that when Handcock's motor coach was fairly established, besides the regular services, there were scores of steam power vehicles running on our highways, in spite of the opposition raised by the stage-coach proprietors who initiated the opposition of the turnpike trust.

Then came the railway mania, and the work of Handcock and other British engineers was forgotten. Even the clumsy but serviceable steam traction engine was looked upon with suspicion by the railways, and its expansion was checked by the Act of 1865. But this year of legalised mechanical road transport oppression—1865—saw the birth of the invention of Lenoir, which, with the modifications he and Otto succeeded in making, is known as the Otto cycle gas engine. The applications of this cycle with petrol fuel to motor road vehicles was eventually destined to sweep away the restrictions of the 1865 Act. Both German and French engineers deserve credit for their subsequent efforts to secure an economic and facile system of mechanical road transport. Benz and Daimler in Germany, Bollée, Panhard, Levassor, and Bouton, in France, worked for many years in the early eighties with more or less success, and on French and German roads. But their work and their progress had no influence on British road transport development, which was dead or dormant by reason of the fatal Red Flag Act of 1865.

ROAD TRANSPORT PROGRESS.

The pioneer application in 1883 of the Otto cycle internal combustion engine, using a highly volatile oil, such as petrol, was made to a tricycle. Several inventors were engaged in the problem, the more prominent being Benz, Daimler, and Edward Butler, an English engineer. Daimler is credited with having in 1886, built the first practical petrol machine for road transport service, although Benz must also have credit for his success in the same year. The steam power enthusiasts entered the arena in 1888, led by the late Léon Serpollet, who had De Dion and Bouty and other associates in this work. Indeed, it is to Serpollet that the introduction of the automobile into England is due. Serpollet extended the application of the steam engine to a four-seated car in the same year. Realising the inadequacy of ordinary evaporative systems, M. Serpollet invented the flattened small bore or flash boiler in 1889. Herr Daimler was equally energetic in the development of the Otto cycle gas power engine, and in the introduction of his two-cylinder petrol engine on the road in 1889, which marked an epoch of progress in the evolution of mechanical road transport methods.

The advance to the motor car came in 1889, both steam and petrol combustion engines being employed. The successes of many inventors rapidly followed, the advances including the application of power to a tram-car in the same year. The rapid development owed something to the fillip given to the industry by the introduction by Dunlop of the pneumatic tyre. So enthusiastic were the French workers, that a petrol motor-train is said to have been made in 1894. The experience of Serpollet upon the introduction of his steam-power car into England, although pretty well known, is worth repeating here. He found to his utter astonishment that the speed of his car was controlled by the 1865 Act of Parliament, and that the speed rate in a town was restricted to 2 miles per hour, and that his car had to be preceded by a man 20 yards forward carrying a red flag. Serpollet was therefore compelled to show the steering and speed qualities of his system on a pathway surrounding one of the metropolitan gas holders.

The history of the attempts at progress made by Sir David Salomons, Mr. Worby Beaumont and others, is well known. The early pioneers of the motor car in England combined in 1896 to form the Motor Car Club (the parent of the Automobile Club) and then commenced strenuous attempts to remove the legal incubus constituted by the Act of 1865. As a result of these efforts, the Road Emancipation Act was passed, receiving the Royal Assent in 1896. The legal barrier being removed, the introduction of Continental cars followed rapidly. By the Act of 1896, automobiles were allowed to be driven at speeds up to fourteen miles per hour, and the red flag restrictions were removed. The Act is restricted to vehicles propelled by mechanical power under three tons in weight unladen, and not drawing more than one vehicle. The vehicle and its motor is not to exceed four tons in weight unladen. The passing of this Act would not have been accomplished but for the strenuous work of Sir David Salomons and Mr. Worby Beaumont, a past president of this Society, than whom no one deserves greater credit for the work done in clearing the way for the coming of a new industry of immense possibilities for the good of the country.

Since the passing of the Act of 1896, the expansion of the motor-propelled road transport vehicle industry has been marvellous. Merely taking the application of the motor to the metropolitan 'buses, we have some startling figures. Only two years ago the number of motor 'buses could be counted on the fingers of one hand. To-day the figure is probably 800, and their capacity for passenger transport is proved by the fact that last year they carried four millions of passengers in excess of the tramcars of London or above 185 millions, and over distances approaching 30,000 miles a year: the total distance travelled by the 800 'buses would equal 24 millions of miles. Although the cylinders of many of the motors at the end of a year's run show no signs of excessive wear, the rates of maintenance and of depreciation are very serious items in the running costs.

Unfortunately, the application of the motor to omnibus vehicles has been too hurried and too rapid, and but little real progress has resulted. The economics of transport work have not been properly studied, and respect for the surface maintenance of our roadways has been considered to be a negligible quantity. The effect of this want of consideration is forcing forward the question for Parliament of new Acts to safeguard the highways, and secure the cost of their maintenance being borne by the users of such highways.

The regrettable fact of the hustling propensity is being proved by the unsatisfactory structural character of the motor-bus and its transmission and rolling gearing and wheels, the depreciation being actually rated at 20 per cent. In other words, it is necessary, in the balance-sheet of expenditure and revenue, to assume a useful life value of only 5 years. Such a charge on the revenue endangers the economic value of this popular system of passenger road transport. Apparently, this item in the running costs has not been counted by those who are responsible for this invasion.

Solution of the Reduction Problem.

The authors suggest that the solution of the problem of effecting a reduction of the depreciation and maintenance incubus of the motor element, that is threatening the commercial existence of the present motor-bus may be found in the application of the Heilmann principle. Herr Heilmann adopted the principle of electrical transmission between a high-speed steam engine and the axles of a railway locomotive. The following letter addressed to Mr. Thwaite by the late Mr. Chas. Brown, describes the results of the tests of the Heilmann locomotive. The letter appeared in 'The Engineer' of September 1, 1893. "It may interest you to hear that the big Heilmann electric railway locomotive was started last Monday. It runs wonderfully sweet, and the faster she goes the better and the smoother, the disturbing influences of the masses being entirely eliminated. There is no counter weight on driving wheels, but a steady tangential pull at the tyres. This, added to the compensating action of the compound bogie combined, produce a locomotive which runs with remarkable steadiness."

Similar to the Heilmann principle, the authors would suspend from the chassis and with suitable compensating springs both the motor and its associated dynamo, so that liability to damage and excessive wear by reason of shocks and vibrations would be greatly reduced, as the only connection to the electric motors on the hubs of the driving wheels or to a counter shaft, transmitting the power to the wheels by link chains, would be a wire. The effect of unequal road surfaces and the vibrations set up by variable speeds and road obstacles, would be negligible, and the wear and tear, and cost of maintenance and depreciation should be reduced by one-third at least.

Even supposing that the loss of power in transmission equalled 15 per cent., this only exceeds the average loss (say of 10 per cent.) by 5 per cent., so that the fuel costs of 12½ per cent. would be increased by 2½ per cent. Against this, the reduction of the maintenance and depreciation charges, say of 40 per cent., by one-third, would be equal to 13·3 per cent.; deducting 2½ per cent. would then mean a balance in favour of the electrical method of power transmission of 10·8 per cent. The elasticity of the electrical drive, its rapid and easy control, and the facilities of application, are additional advantages.

TECHNICAL TRANSITION OF DEVELOPMENT.

The most important phases in the technical transition in road motor vehicular development may now be briefly discussed. The mere enumeration of the transitionary phases of the road motor evolution, since Handcock's motor coach ran over London's highways, would alone fill a book, so that the authors will merely mention the more salient features of the changes in the character of the motor and the methods of power transmission that have led up to the modern system of road transport. Before doing so, however, they will endeavour to broadly define the basis.

TRANSPORT EFFICIENCY MEASUREMENT.

The only economic test of a system of transport is the cost of load carriage per ton mile. But another test that gives the efficiency of the system is the carrying capacity of a given system at a given speed. This last test may be formulated as follows, where the cost of power is assumed to be equal.

Let a = the full live load capacity of a train in tons.
b = the weight of a train and its motor.
c = the maximum speed of a train carrying the maximum load.
d = cost of repairs and depreciation charges per ton mile, maximum speed full load.

Then $(a - b) \times \frac{c}{d}$ will provide the figure of comparative efficiency.

Comparative lightness on roads of any motor road transport system will best be secured by determining the pressure on the road surface per square inch of tyre. This is, of course, assuming the tyre is smooth and not corrugated or barred. To secure adhesion at the cost of the public road surface, may be a good and economical policy for the owner of the tractor to adopt, but the road authorities have a right to protest against this policy.

Doubtless, the tendency of modern transport inventions to return to the road will be followed eventually by a return of the toll bar system, and it is very probable that the tolls will be proportionate to the wear and tear characteristics of any given mechanical road transport system; indeed, this would only be fair. It would indirectly provide a premium for the best designed vehicular system. If the density and hardness of the broken stones used for making a road were superior to the crushing effect of any vehicle that ran on such roads, then the pulverising effect would be negligible and outside the effect of horseshoes; this road would remain good for a long period. If, therefore, the loads on a transport vehicle were so well distributed that none of the wheels were capable of producing a crushing effect, such a train should constitute a standard type for road service, and the tolls charged should be on the lowest scale.

STEAM POWER MOTORS.

The problem that faced the advocates of steam as the agent of propulsion, was how to secure the maximum heating and evaporating surface, in proportion to weight of steam generated. This had one solution, in the flattened small bore tube steam boiler of Léon Serpollet. The question of steam condensation was equally important. Air adds no weight to the vehicle, and it is a constant environment, whereas water has to be paid for, and it is heavy, but it is a more effective cooling agent. A combination of the two has been effected.

Then as to the motor. Serpollet was faithful to the single-acting piston type, until the success of the double-acting type compelled him to abandon the former and adopt the latter. The importance of securing the maximum possible power for a given weight of structure (static and dynamic), led Serpollet to attempt to exactly proportion the supplies of the three essential agents, water, petrol, and air, so as to secure the best results. This is a step in the right direction, and will succeed, providing all the agents are attainable of a pure character; that is, the petrol of a constant specific gravity, the air free from road dust, and the water soft.

PETROL POWER.

The introduction of the petrol internal combustion engine brought forward new problems. The obvious defect in the single engine was the irregular character of the power, or live stroke, impulses, one active stroke in four producing tremors and vibrations of the engine structure, unpleasant to the user and destructive to the machine. By the simple expedient of a multiplicity of cylinders and pistons acting on multiple cranks, so disposed as to distribute the live impulses equally over the crank circle, a steadiness and uniformity of running proportionate to the number of cylinders, with an equivalent increase of power has been secured, and with a reduced weight ratio in proportion to such power.

The reduction of the nuisance of the exhaust has been easily effected by the breaking up of the sound waves, and there is less noise today from a 70-horse power than followed the trail of an early single-cylinder type of ten years ago. The problem of securing adequate cooling of the cylinders has points of similarity to that of the steam condensation, and the solution of the problem is arrived at in a somewhat similar manner. The cooling of the cylinder heads containing the valves and spindles has removed many difficulties due to expansion and overheating effects. The devices introduced for the production of combustible vapour from petrol and other volatile liquids are legion, but there is still no standard carburettor system.

There is a considerable margin for a thermodynamic efficiency improvement in the petrol motor used on road transport vehicles. With a modern blast furnace gas engine, the authors would not be satisfied with a thermodynamic efficiency equivalent to an expenditure of 9500 B.T. units per B.H.P. per hour, whereas the ordinary petrol motor in the actual work probably involves an expenditure of from 12,000 to 15,000 B.T. units per hour under the best load conditions.

The ignition of the explosive mixture of petrol vapour and air by Bosch's magneto is rapidly becoming the universal standard: it has secured the victory in the struggle with the tube and the coil-spark ignition.

TRANSMISSION OF POWER.

The great advantage of the indirect and really rotary transmission of sprocket gear, compared with the staccato impulse of the direct drive of the locomotive has not been realised by railway engineers in general, although Heilmann attempted the application of this principle for locomotive driving in France, and the steadiness was such that it is said a glass of water could be carried in the tender without the loss of a drop. The advantage of the indirect drive is the facility of increasing the speed of the motor in ascending stiff gradients, whereas in the direct drive the piston reciprocations are limited by the speed of the driving wheel of the locomotive.

The transmission problem for road motors is solved in various ways, but what appears to be the survival of the fittest of the purely mechanical methods is the use of a propeller shaft equipped with Cardan joints, coupled through a clutch with the crank shaft. Of course, the ideal system will be defined in relation to the character of the roadways.

The direct drive from the motor crank shaft would for average roads be quite impracticable, so that the usual method is to mechanically drive a horizontal shaft through bevel and worm gearing. Through the introduction of an ingenious ball gearing by Mr. Collier, the latter is likely to become the standard mechanical system; generally the link chain is employed to transmit the power to the live wheel.

The flexibility of the chain drive has secured its almost invariable application for the lighter road motor vehicles. The universal system of varying the speed ratios for hill-climbing, etc. is the employment of gear ratios on the propeller shaft, the mere movement of various ratio gears into mesh is all that is required. This system has survived through almost all the changing stages in the history of the road motor evolution, since the date of Panhard and Levassor's work. The propeller shaft is put in gear by means of various clutches, but whether the ideal system of clutch has been found is still undecided. The efficiency in power transmission of the different systems, assuming good workmanship and materials have been employed, with well proportioned elements and circulated lubricants, is fairly satisfactory. The range in actual practice, will vary between 84 per cent. and 96 per cent., equivalent to a loss of power respectively of 16 per cent. to 4 per cent.

The ingenuity that has been displayed in varying the moving parts in attempts to secure improvements is extraördinary, and has only a parallel in the history of the evolution of textile machinery. The demands of the motor industry in special steel has necessitated research, that cannot fail to be useful to the metallurgical industry. Even the wheels and their resilient tyres have stimulated the inventive faculty to a remarkable extent. The flexible and resilient tyre of Thomson in the early history of the movement, and the pneumatic tyre of Dunlop, have both done real service to the development of the road motor, and constitute the most important British contribution to the building of the industry.

The problem of steering has been fairly well solved by Akermann, whose system is far superior to the early turntable system. The skidding danger has been forced to the front by the erratic movements of the motor-buses that have during the last year been imported from Berlin and other places. The centre of gravity of this heavy type of passenger road motors being so high, and the tangential effect of the movements of these vehicles being so considerable, the wonder is that the skidding danger is not even greater. The railway system has this advantage, that the centrifugal tendency can be compensated for by the super-elevated rail. No equivalent remedy has yet been found for road transit.

The Renard and Sourcouf System.

The latest development of motor road transport, namely the Renard and Sourcouf system, has not proceeded at the rapid pace of many of the other road motor developments. The inventors, the late Col. Renard of the Corps of Engineers of the French army and his associate, M. Sourcouf, have given careful attention to almost every problem that would have to be solved in practice to secure success for mechanical road transport for most kinds of traffic. Amongst the problems to be faced are included the following:—

The utilisation of the useful or paying load to provide propulsive adhesion.

The extension of the live-wheel base in proportion to the length of the train.

The lowering of the weight on any part of the wheel base and its adhesion tread, so that the road surface should suffer very little, and so that the vehicles could be permitted to cross any bridge accessible to horse-hauled vehicles, without involving any danger to the stability of the structure. To obtain the maximum area of adhesion, and to secure the easy starting of the transport system.

To secure in a multiplicity of vehicular units, a system of coupling that would provide rigidity with such flexibility, that the coupled units could pass round on a rail-less road in a circle of 12 yards diameter.

To secure steering control either forwards or backwards over the coupled units from either end, in a practical and effective manner from one of the vehicles.

Claims of the System.

A train of vehicles possessing the qualifications sought for, would, from the standpoint of the road authorities, possess the following claims for preferential consideration.

1. The distribution of the weight of the train on the road surface spread over a long wheel base, and over many rolling contacts carrying the dead and live load of the train.

2. More than the proportionate reduction of the road surface

wear, because the density and strength of the road material would resist the crushing effect of the well distributed pressure over the road, whereas an ordinary heavy traction engine would, by its limited wheel base and heavy wheel pressure, crush the road materials into dust.

3. The same advantage of light distributed weight over a long wheel base, applies to the movement of the train over bridges and like structures. A bridge quite incapable of supporting the heavy concentrated weight of a traction engine, will be undisturbed by a similar weight distributed over four or more axles at intervals of from 12 to 15 feet apart.

Moreover, the mechanical system of the wheels of the chassis of each coach is vertically elastic, so that an obstacle in the road is surmounted without appreciably disturbing the balance of the chassis structure.

The inventors have apparently recognised every circumstance associated with road transport, and they have attacked the problem in a mathematical and scientific manner. In the opinion of the authors the system is a distinct and important departure from the orthodox methods of mechanical propulsion on land.

ADVANTAGES OF THE SYSTEM.

The Renard system is obviously independent of any particular method of propulsive power generation, as either petrol, gas, or steam power may be used. So far the convenience, lightness, and reliability of petrol fuel has justified its general use; besides, the running cost appears to demonstrate that, at the present prices of petrol and rates of wages, the cost of power for propulsion is not the all-important element.

There is a general resemblance in the following statement illustrating the analytical character of the running costs of two typical systems of mechanical road transport, and which is based on Col. Crompton's figures. The conspicuous feature is the incubus of the depreciation and maintenance charges, and the cost of labour:—

Type of Motor.	Wages, per cent.	Repairs or Maintenance and Depreciation, per cent.	Fuel and Lubricants, per cent.	Water, per cent.	Insurance, per cent.
Steam tractor with trailer . . .	39·4	37·0	13·5	4·9	4·0
5-ton petrol wagon .	26·6	52·3	17·1	included in petrol costs	4·0

Again referring to the question of how these heavy depreciation and maintenance costs can be reduced. Can the high rate of piston reciprocation and piston speeds with corresponding valve movements be reduced? Can the excessive vibration of the chassis be stopped by the application of well designed compensating springs, or by the suspension of the motor, from the chassis? The excessive tremors set up must tend to make the moving parts very brittle. The use of fuel of lower calorific value in cylinders of larger area may secure a less violent impulse on the piston, and the strains set up would be lessened. The provision of piston liners easily replaceable, and the adoption of the principle of effecting repairs in good time, will assist in prolonging the life of the motor.

The comparative absence of ruts in the roads, and the work of ploughing through or rolling over, the road material, in the Renard system, will be an obvious advantage due to the distribution of the load over the tyres of the wheels. Again, each driving wheel having an elastic or spring coil, there can be no sudden strain brought on the power transmission shaft. The compression spring permits the accumulation of the energy to a point that will set the train in motion.

As the effective adhesion of the Renard system is distributed over the entire length of the train, if the surface of the roadway at one period is incapable of supplying the necessary adhesion, the cases will be rare in which it will be found that the wheels of the other part of the train do not secure the necessary grip on the road.

THE RENARD SYSTEM.

The following is a general description of the mechanical road transport system of Col. Renard; a train of which is illustrated in Fig. 2. One of the most important conditions leading to economy in all mechanical transport systems, but more especially those running on roads, is that the weight on all the axles of a vehicle or a train of vehicles should be equal or nearly so. In ordinary systems of mechanical transport, it is difficult, and, indeed, in many applications, quite impossible, to obtain this equal distribution of weight, because the weight on the driving wheels must be adequate to secure the necessary adhesion to haul the train. Col. Renard has solved the problem by transmitting the power developed by the motor through a rotating longitudinal shaft to one axle of each of the vehicles that make up the train. This rotating shaft is fitted with universal or Cardan joints, to enable the train to take curves and navigate the traffic in crowded thoroughfares.

The weight of the motor for such a system of power transmission need not therefore be greater than that of an ordinary motor-car of equivalent horse-power. The vehicular units of the Renard train are usually mounted on three pairs of wheels, the centre pair in each case being driving wheels. The weight on the several axles of such a vehicle is regulated by means of compensating levers, so that each axle carries an equal portion of the load, even when one pair out of the three pairs of wheels passes over an obstruction, such as a baulk of timber 6 inches high. Equally ingenious is the steering arrangement of the entire train. The system consists of an arrangement of levers, by which the leading and trailing wheels are slewed through the angle necessary to bring them to a position tangential to the curve round which the preceding vehicle is travelling.

As the tail end of the first vehicle swings round on the curve, it bears on a tiller rod connecting the two vehicles, and turns the front axle of the second vehicle in the required direction, and this axle, by means of a knuckle joint in the centre of the chassis, turns the back axle in the opposite direction. The accuracy with which each vehicle follows in the track of its predecessor is remarkable, the actual divergence of the tracks of the several wheels seldom being more than one inch. To prevent excessive back slip of the inside wheel on the driving axle when the vehicle is rounding a sharp curve, the hubs of these wheels are fitted with compensating springs. The brakes are applied to a drum mounted on the transmission shaft of the motor, so that all the driving wheels throughout the train are braked simultaneously.

Description of the Mechanism.

The transmission shaft of each vehicle consists of the parts 1, 2, 3, 4, and 5, connected together by universal joints, as shown in Figs. 4 and 5. The length of transmission shaft between two vehicles (not shown in the figures) is telescopic, to allow for the variation in distance between the vehicles when passing over uneven ground, or steep gradients. Differential gearing mounted on length 2 and inclosed in gear box 10, drives the countershaft 12, which in turn drives the chain drum 16. This drum is not rigidly attached to the hub of the road wheel 14, the power being transmitted from the former to the latter, through the spiral spring shown at C, in Figs. 6, 7, and 8. A and B in the same figures, form part of the hub of the driving wheel, the chain drum *g* being free to revolve independently of it. Between the stud F, which is fixed to the drum casing G, and the two lugs D D which form part of the hub of the wheel, the spiral spring C is wound. When the drum is revolved by the driving chain, the stud F compresses the spiral spring, the other end of which then presses on the lugs D D, causing the wheel to revolve. The play allowed by transmitting the driving power from the chains to the wheel through this compensating spring, minimises the slip that would otherwise occur between the tyre of the inner wheel and the road surface, when the vehicle is travelling round a sharp curve. Another good effect of this elastic connection, is the reduction of the violent shocks so generally experienced when motor 'buses and wagons are suddenly started.

To insure the equal distribution of load over the three axles of the vehicle, the ends of the laminated bearing springs are connected together and to the body of the vehicle, by the compensating levers 1, 2, 3, and 4, Fig. 3. By this arrangement all the wheels are forced to bear on the road surface with an equal intensity of pressure, even when one wheel is raised considerably above the other two by the unevenness of road surface or the intervention of some obstacle. This arrangement enables the train to pass over uneven roads and even pieces of timber 6 inches high, without jarring either the passengers or the mechanism of the train. This compensating gear is somewhat similar to that used on the heavy tank engines of the Metropolitan Railway for many years.

The accurate steering of each vehicle is effected by the arrangement of the levers and links shown in Fig. 9, which illustration has been kindly lent to the authors by *The Automotor Journal*. At each end of the vehicle a pivoted clutch H is mounted on the frame of the chassis, and is connected by crank levers to the links H_2 and H_4. Links H_2 and H_3 form two parallelograms, one under the front and the other under the back portion of the chassis. Links H_4 operate ordinary Ackermann steering gear attached to the front and rear axles of the vehicle.

By means of a knuckle joint between the links H_2 and H_3, the direction of motion of the parallelogram at the rear end of the chassis is reversed, so that both the front and back wheels are always set tangentially to the curve round which the vehicle is travelling. Between the rear clutch H of one vehicle and the front clutch of the next, a tiller rod is connected. As the first vehicle swings round on a curve, the tiller rod operates the steering mechanism of the succeeding vehicle by deflecting the clutch H, mounted on the front of it.

When the train is moving forward, the front clutch H is locked, so as to make a rigid connection with the crank lever: the clutch at the rear of each vehicle is, however, unlocked and therefore free to turn through a considerable angle, so that the steering mechanism of the second vehicle is not actuated until the rear of the first vehicle swings round on the curve and deflects the tiller rod.

Fig. 10 shows the brake drum C mounted on the transmission shaft of the motor chassis. The rod A is connected to the brake levers controlled by the driver. This rod actuates the brake blocks B, causing them to grip the brake drum. By arresting the movement of this drum, the brake is simultaneously applied to the driving wheels of all the vehicles of the train, through the medium of the transmission shaft.

FUEL CONSUMPTION.

In the War Office trials carried out on February 18, 19, and 20 of the present year, the consumption of fuel on the 35 miles run between London and Aldershot worked out at 0·35 lb. per gross ton mile on the down journey and 0·345 lb. on the return journey. The gross weight of the train and its load of bags of sand and passengers was 19 tons, and the average speed from start to stop was 5·42 miles per hour on the down and 6·1 miles per hour on the up journey. The fuel was the ordinary petrol used by motor omnibuses, having a specific gravity of 0·72 and costing 7*d.* per gallon. During these tests, the road surface between London and Egham was in good condition and the weather was fine. On the Egham to Aldershot portion of the route, the conditions were not so favourable, many long stretches of the road being under repair and also soft and greasy from rain. The train ran quite steadily at 10 miles per hour. The average speed over ten consecutive miles was 8·7 miles per hour.

HILL CLIMBING.

A hill over a mile long on the main road near Aldershot was chosen by the War Office officials for the purpose of testing the hill-climbing capabilities of the train. The gradient of this hill varied from 1 in 38 to 1 in 10, the average gradient from top to bottom being 1 in 18·8. The train easily took this hill at an average speed from bottom to top of 2·44 miles per hour.

ADVANTAGES.

Some of the advantages that the Renard system possesses over ordinary methods of mechanical road traction are summed up as follows:—

1. By the adhesive load necessary to propel the train being

distributed over one-third of the axles of the whole train, instead of being concentrated on one axle as in the case of traction engines, the wear and tear of road surfaces and damage to bridges, is reduced to at least one-third. The heavy driving wheels of the ordinary road locomotive not only crush the materials of which the road surface is composed, but by the grinding action of these heavy driving wheels the crushed particles of the road surface are torn from their bed. It is evident that by spreading the adhesive load over four axles the damage to road surface caused by both the above-mentioned actions will be reduced in the same proportion.

2. By the application of the brake blocks to the surface of a drum mounted on the transmission shaft of the engine, all the driving wheels throughout the train come under the action of the brake simultaneously, the train can be brought to a standstill very quickly, and at the same time only causing a fraction of the damage to road surface that would result from a train of similar weight being stopped by brakes applied to one pair of wheels only.

3. In a train of four vehicles, there are four pairs of driving wheels distributed at equal distances over the whole length of the train, so that in the event of the driving wheels of the first vehicle getting into a bad piece of road and therefore losing their grip on the surface, the remaining three pairs of driving wheels—some of which at any rate, will probably be on a firm surface—will continue to propel the train and push the first vehicle over the soft hole. This will enable the train to take outlying country roads (which are frequently in a bad state of repair) better than any of the ordinary motors and engines which depend for adhesion on one or more pairs of driving wheels concentrated at the head of the train.

4. The effective steering gear enables many vehicles to be run in one train with perfect safety to itself and the other traffic using the road. The cost of wages of drivers and van men, which at present forms a heavy proportion of the total money charges in all mechanical road traction methods, can therefore be considerably reduced.

5. The cost of upkeep and repairs can also be reduced considerably for the same reasons, as there is only one engine for 4 or 5 vans, and the engine is the most expensive unit to maintain. On the trains that have been running during the last two years in France the cost of repairs to transmission shaft and gearing on the other vehicles has proved to be very small.

6. The introduction of three pairs of wheels under each vehicle with the load equally distributed over them, even on uneven road surfaces, should form a great safeguard against side

slip. The behaviour of the train while passing round sharp corners at considerable speed on the recent War Office trials certainly strongly confirms the correctness of this deduction.

So far the authors have not had the opportunity of testing the power absorption of the transmission shaft and gearing, but as a matter of fact, the shaft *per se* can be easily turned by hand. On a straight run the loss of energy should be comparatively small, but in passing round curves, the opinion of the authors is that the loss of power may be of some importance. But considering that the curved proportion of any normal road is small in comparison to the straight part, the loss of energy should not materially affect the economy of the system.

The motor road train for goods and for passengers, in its full development and perfection, will provide transport facilities for many agricultural and mining districts which would fail economically to justify the construction of a light railway. The system therefore provides a missing link in the available transport systems of the day.

DISCUSSION.

The CHAIRMAN said that the present was the first paper on the subject of the Renard System, read before any scientific society in this country. He was sure that the members would agree with him that it was of great interest to all who had specially to do with road traction; and it was also interesting to those who were required to provide a road which would stand the blow of horses' hoofs, and a concentrated load upon one or two wheel points, and at the same time afford a surface which would be suitable for the modern development of resilient wheels. He was sure that the meeting would join very heartily in thanking the authors for their interesting paper.

The vote of thanks was carried by acclamation..

Mr. W. WORBY BEAUMONT said that the main question which lay at the bottom of the paper was the distribution of loads over a number of vehicles, but before they came to that there were certain details in the paper to which attention might be drawn. He would begin by reference to the author's statement that, "The regrettable fact of the hustling propensity is being proved by the unsatisfactory structural character of the motor-bus, and its transmission and rolling gearing and wheels, the depreciation being actually rated at 20 per cent." It was perfectly true that 20 per cent. had been adopted by those who had been conservative in the matter, and 20 per cent. and even more had been found necessary by some of those who had purchased and used motor omnibuses without any reference to the actual character of the things which they were using. He did not think that it was necessary, and although the experience of the authors might give them a good foundation for looking upon 20 per cent. as not enough, he did not quite agree with them in that, and he was perfectly satisfied that it would not be very long before a great deal less than 20 per cent. would be sufficient to cover that which was properly to be called depreciation.

Of course, there was some difference of opinion as to what should be taken as depreciation. In a general way one took the cost of replacing a vehicle as representing the total amount that had to be deducted from the earnings so that they might, at the end of a certain period, be in a position to replace the worn out vehicle free of cost. It was perfectly obvious that if a vehicle could run for five years and was properly maintained, so that it would run for five years, it did not cease to be of value at the moment that the five years were up. They might, therefore, agree with those who said that depreciation should have reference to the value of the vehicle at the end of the time, whether to be used for the same purpose or for other purposes. A great many of the vehicles used for street racing through London, would do for slower work such as cart horse work later on.

The next point in the paper for notice was the following. "The authors suggest that the solution of the problem of effecting a reduction of the depreciation and maintenance incubus of the motor element that is threatening the commercial existence of the present motor-bus, may be found in the application of the Heilmann principle." He thought that no one could doubt the value of the introduction of some arrangement that would give a gradual change from no velocity to full velocity without any steps or changing of gear wheels in mesh, and an arrangement such as was more or less fore-shadowed by the Heilmann combination, and which was being carried out by other means in vehicles that were now under trial, might have considerable practical value, but at the present time they were not commercial.

The paragraph relating to roads was one which he thought was at the bottom of the whole of the question, and the most important one touched upon in the paper, inasmuch as it dealt with the cost of running the load that could be carried. He did not think that they could too often reiterate the argument which had been put forward from time to time as to the importance to the whole community of improvement, to some extent in the construction, but mainly in the maintenance of the roads.

They put up with a very great deal of inconvenience for the sake of having what he called a good excuse for a bad road, namely, a tramway in the street merely for the sake of getting smooth running and lower tractive resistance, and he thought that it must be obvious to everybody—even to those who did not remember that their broughams were knocked to pieces or that their axles were broken in the road by getting across the tramways—that it was highly desirable that everyone should begin to see that it was to the interest, not simply of those who were driving or using the vehicles, but to everybody in the country, that proper attention and proper expenditure should be devoted to road improvement.

There was a further statement on the same subject to which he would like to direct attention; that was to the effect that the modern transport inventions might cause a return to the turnpike system. Well, if they could not get better roads by other means let them by all means return to a toll system for payment of upkeep by competent authority, not for payment of road-farmers as in old days. If there was any one subject which the state should undertake as being a matter of importance to every member of the community throughout the whole country, it was road construction. There were today nearly double the number of millions of people occupying this country that there were in the days when they began to employ able engineers to make and improve the roads, and yet there had not been 10 per cent. of new main roads made in the country since that time, in spite of the enormous increase in the population and corresponding necessity for increased road traffic accommodation. Therefore, it might easily be seen that a great deal of money might usefully be spent in the construction of new roads on definite lines.

The authors had referred to the density and hardness of the broken stones used on the roads, but he would point out that it was not simply a question of the hardness or density of the stones used, but it was very much more a question of the way in which the stones were compacted and formed into a road surface when they had been broken to the proper size. Unless some other means than those generally adopted were employed they would never get a really satisfactory continuous hard or homogeneous surface. Under the ordinary system of completing a road surface there must be an almost continuous recurrence of the hard and the softer places in a road, and that condition and the reasons for it were as of great importance as the materials which were selected to make the roads, assuming that ordinary materials were employed.

As to the system which the paper described there could be no doubt that there were situations in some countries where the system would be of service; but there came the question of what were the suitable circumstances, and where were the suitable places. The system would not be useful everywhere, and one point to be considered with regard to it and to closely inhabited countries, was what appeared to him to be the fact, namely that an arrangement of that kind, which offered the greatest benefit when it was being used as a considerable and a continuously used train, offered the means of conducting a traffic which had become big enough to call for a tramway or a light railway. The tramway or the light railway should be off the ordinary road and therefore relieve the ordinary road of the train traffic. The reduction in the load per unit or per wheel, of course, must be admitted as a very important point in the recommendation of the whole system. But when they considered the other points which he had mentioned it would be undoubted, he thought, that the field, or perhaps he should say the roads, for the use of this particular system were more limited in number than might at first sight seem, although it had been proved that the train could be used and had been used.

Sir JOHN MACDONALD said that he had looked upon the introduction of mechanical traction on roads as of far more importance to the commercial interests of the country than for pleasure driving. He had for years been urging upon the Automobile Club and the other organisations connected with the system of mechanical traction on roads, that they should devote themselves to that part of the subject which touched the commercial interests of the country, in view of the great benefits which could be conferred on the community by some good means of traction for the carrying of agricultural produce and minerals, and other goods. Nobody could doubt that the railways were getting very much congested and were much too tyrannical in the rates that they charged our citizens for the transport of goods. While the foreigner could send his goods to this country and have them conveyed 100 miles for a sum which he would call one shilling, the people on the spot who wished to have their goods conveyed the same distance on the same line would have to pay perhaps three shillings. That was a state of matters very serious and very unsatisfactory. He would like to see the roads revived, not merely for the ordinary passenger, but also for the purpose of conveying the goods of the country which did not require to be carried at a very great speed. That was hopeless until they got the nation to realize that we must have good roads, and that it was a subject of national interest to have roads which would not form dust in dry weather, and mud in wet weather. The injury done by dust caused a great deal of annoyance, but the injury done to the road by the formation of mud was infinitely greater. The commercial loss which took place in three months of wet weather through the injury to horses and vehicles and the delay of transit caused by mud would, if calculated, come out at a sum which would astonish anybody who heard it.

The invention of Colonel Renard seemed to be very suitable for getting over the present difficulties, but he felt strongly that the road was the first question. The system which the authors had brought forward certainly seemed to have a great deal to recommend it, but he would point out that it would be impossible to bring it into use without fresh legislation. At the present moment it would be illegal to take such a train along one of our roads. The law did not allow more than three vehicles linked together to be taken along a road, and in the case of those three, the speed was limited to a rate which would be absolutely useless for passenger traffic, and very slow for goods traffic.

He had the greatest possible objection to any reintroduction of the tollbar system. That was the very worst system, for those who lived within the bounds of two tolls paid nothing for the roads they were using every day; and those who came into those limits were the people from whom the tolls were principally exacted; and the roads on which tolls were charged were not a bit better than those upon which they were not charged. The truth was that after the introduction of railways, the roads were neglected, and the railways absorbed the main traffic of the country. People no longer used the roads either for pleasure or for mercantile purposes. The only carts that went along them were farm carts, and one might go for miles and miles without seeing any vehicles on the roads. Now, however, the roads were being pretty well filled with vehicles; and to say that those vehicles contributed nothing to the rates was absolute nonsense.

He believed that the Renard train was as near a solution as could be got of the difficulty of using the roads without knocking them to pieces.

Colonel Crompton, C.B., R.E., said that during the last year he had been present at fourteen meetings where discussions on road locomotion had taken place. In every case the matter of the roads on which these vehicles had to run had come to the front, but in this case he thought the authors had been unfair to mechanically propelled vehicles when they said that "respect for the surface maintenance of our roadways had been considered to be a negligible quantity. The effect of this want of consideration is forcing forward the question for Parliament of new Acts to safeguard the highways, and to secure the cost of their maintenance being borne by the users of such highways."

He regretted this should have been said as it was not true, and did not truly state the cause of Parliamentary interference being considered necessary. In every one of the fourteen discussions he had alluded to, all persons had agreed that one of the most important effects, that the newly awakened interest in mechanically propelled vehicles running on our highways had been, to call attention to the fact that the highways themselves were in a bad state, not so good as they were in the coaching days, and engineers generally were agreed that the time had come for the highways themselves to be greatly improved.

The experimental work which had been carried out during late years to toughen or consolidate the top of the road metal so as to hold the materials firmly in place, not only in wet weather but also in extremely dry weather, had been to show that there was a reasonable prospect of such consolidation being satisfactorily performed, and that thereby, not only the dust nuisance, but also the cost of maintenance of the roads themselves would be greatly lessened. In the case of the metropolitan omnibuses referred to, one great cause of the noise and rattle complained of was the very bad state of the surfaces of parts of the roads over which they had to run.

This evening, for the first time, a system of road locomotion was put forward which seemed likely to greatly reduce the cost of road maintenance on four-fifths of the highways of the United Kingdom. The Renard train described showed the first serious attempt to distribute the weight to be carried over a greater number of wheels, and to distribute the driving stresses also over a greater number of wheels. These two stresses taken together, were the two factors which determined the wear and tear of a road, and consequently, eventually determined the wear and tear of the vehicle itself, as, if the road itself was maintained in good order, it re-acted on the vehicle by reducing the wear and tear of the vehicles themselves.

Another good point in the Renard train was the introduction of six wheels to each vehicle. Every railway engineer knew that he could not allow four-wheeled locomotives to run over his system, as a four-wheeled engine could not stand upon three wheels, whereas a six-wheeled vehicle could stand upon five wheels. It followed that although any wheel of the four-wheeled engine must necessarily fall down into any hole or depression in the rails or road, it was not necessarily the case with the six-wheeled engine, as the wheel over the hole or depression need not go down into it, the weight of the engine remaining distributed over the other five wheels.

For those reasons he wished success to the Renard system, which was well suited to carry loads over weak roads. He had stated that four-fifths of the roads of England were weak roads. By that he meant that they are formed with a fair or good surface but with little or no foundation underneath the coating of metal. Such roads, although they could stand light traffic, suffered heavily when mechanical traction carrying heavy weights on the older systems was run on them. On good roads having a good foundation, mechanical haulage could be carried out on the older systems without the roads being damaged, but with weak roads without foundation the case was different. When heavy weights were brought on to them either in the traction engine wheels or on the wagon wheels following them, the weight of the engine simply depressed a slice of the road equal in width to the width of the wheels, and thereby ruts were formed and the road surface became broken up. That effect was avoided by the Renard train, for the weights on each of the wheels would be so low that all existing weak roads could carry those weights without additional strengthening. It was easy to see the enormous saving in the cost of reconstruction of roads if this necessity of putting in better foundations to our weak roads could be avoided.

The idea of a train of long wagons drawn by an engine was not new; he had conducted the Government steam train in India from 1869 to 1875, and had run trains of 19 wagons in addition to the engine. They were very successful with those long trains, but they had not the advantage of the steering arrangements of Colonel Renard which had been perfected by Mons. Sourcouf. Therefore, whenever they exceeded a certain speed, any irregularities, or side sway of the engine were exaggerated at the back of the train, so that at the higher speeds, such as when descending long inclines, the end of the train began to sway about like the tail of a kite and occasionally the couplings of the last wagons were broken and the wagon seriously damaged, which, of course, added to what the authors call the maintenance cost of the system.

It was evident that the six-wheeled vehicles used had greatly reduced, if not entirely prevented, the liabilities to side-slip, and that had been corroborated by experiments which the Automobile Club had been recently making in some of their competitive trials, in which the six-wheeled omnibus did not make those gyratory movements which we had been accustomed to associate with a motor-omnibus.

Another point the authors had touched upon, and which he corroborated was, that the Renard train would not be brought to a standstill by a short greasy bad place in the road, where, on account of defective adhesion, the ordinary train could not proceed. In the late Cape war, during the rainy season in

Natal, traction engines were much limited in usefulness by wet and slippery places occurring on the routes taken by the army. The authors had pointed out that the Renard train overcame that difficulty, as the propelling power being distributed over the whole of the train, the adhesion only of that pair of wheels immediately over the slippery place was lost, but the adhesion of the remaining wheels on the firm ground was sufficient to propel the train through the bad place.

He was sorry to differ from so great a legal authority as Sir John Macdonald, but he thought that the Renard train could be steered through the Act of Parliament easier than the proverbial coach could be driven through it, as the coaches of which the Renard train consisted were not trailers, but were each of them self-propelled vehicles.

Mr. **Harry S. Foster** said that he had a considerable interest in the Renard train, as he was more or less responsible for its introduction into this country. Mr. Beaumont suggested that the use of that train would be limited in the possible field for its operation, and that it might be useful in some places, while it would not be in others. When he (the speaker) first made the acquaintance of the train, his first impression was that it might be of very great use in our colonies, and in many other countries which were not covered with a network of railways, but that it would be limited to such places. Since then he had had reason to alter his opinion, and he was astonished to learn from such organisations as the Agricultural Organisation Society, that there were many places in England that were practically out of the world through being without railway communication. He had been told that in such places the introduction of the Renard train system would be a great boon.

One advantage which struck him was, that a great many of our branch railways had been constructed, not because it was expected that they would pay in themselves, so much as that they would serve as feeders of the great trunk lines. Those who observed the expenditure of capital from time to time on branch lines, had learned long since that the branch lines had often been an incubus, rather than an addition to the revenues of the company, as far as dividends were concerned. Their immediate commercial results had been small and unsatisfactory, because of the very heavy capital outlay involved in the purchase of the land, and the construction of a heavy permanent way and of bridges, not merely for the purpose of carrying the carriages and trucks, but for the purpose of supporting the heavy locomotive engines which were necessary for the purpose of starting and hauling the train. In the Renard train, however, there was no capital outlay required for the construction of the line. Railway companies, by starting such a system as that of the Renard train could remedy a mistake, if they made one, because, if they found that the traffic between two places did not pay, they would have simply to move their train somewhere else.

A point about which he would speak with the greatest deference, was the opinion which had been expressed by Sir John Macdonald. He (Mr. Foster) had had his attention called more than once to the Act to which Sir John Macdonald referred, and he had discussed the matter, not only with laymen, but even with members of His Majesty's Government; and it had been pointed out—and he believed truly—that all the existing Acts were framed with a view to the necessity of regulations for controlling traffic on roads, where traffic, in the shape of trailers, was liable to misbehave itself in the way that Colonel Crompton had mentioned with regard to the rear wagons of his trains in India. None of those Acts contemplated such a system as the Renard train system, where the various units of the train were under complete control from start to finish, and where each unit of the train followed in the exact track of its predecessor, whether going straight, or turning a corner.

He ventured to think that the definitions laid down in the existing Acts, and particularly the regulations issued by the Local Government Board, would not be held to apply in the case of the Renard train, for in each case the regulations applied to trailers, and a trailer was very precisely defined in the statutory rules issued by the Local Government Board, as being a vehicle which was drawn. With the Renard train, there was no hauling by an engine with so many trailers following it, which was one of the things that led to road destruction. In the Renard system, there was an even movement of the whole train. Each unit of the train, by the very nature of the mechanism, was compelled to start simultaneously, so that the moment that the first shaft began to move, each unit of the train must move forward.

Mr. A. R. SENNETT said that the description of the Renard system suggested to him a conundrum, namely, "When is a trailer not a trailer"? As for himself he would have been inclined to have answered "When it is in a Renard train." He was therefore a little disappointed when Sir John Macdonald told them that he was afraid that the introduction of such an ingenious system would necessitate new legislation; but he was rather relieved when Colonel Crompton brought forward the opposite view, and also when he heard the very clear way in which Mr. Foster put the matter.

Mr. Worby Beaumont had touched upon the important point as to the places in which the Renard train would be useful. He thought that the largest field for that system of traction would be found in connection with agriculture. Sir John Macdonald had touched upon a point which had cropped up periodically in the newspapers, in which indignant letters appeared asking why it was that British agricultural produce had to pay a higher rate on the railways than foreign produce. There was a very good reason for this. He did not think that the average British railway director was so thoroughly unpatriotic that he wished to subject the British farmer to excessive rates, and to treat him less favourably than the foreign competitor. The higher rates could not be avoided because the British farmer sent his produce in such small quantities; and he thought that that fact would give the Renard train a very large field. Time after time chairmen and managing directors of railways had written to say that they would give the English farmer precisely the same rates as were charged for goods arriving by ship, if they would only guarantee a train load, or half a train load, or a quarter of a train load at each station. The cost of transporting agricultural produce depended not only upon the actual cost of haulage, but upon the cost of handling the goods. To reduce that to the minimum, he would suggest the following system in connection with the Renard train for agricultural produce. It should consist of a number of vehicles, the bodies of which should be detachable and made slightly smaller than the standard railway wagon. The tractor should carry a gib or crane capable of lifting one of the bodies. On arrival of the road train at the railway station, the tractor vehicle would be detached, and one by one, the bodies of the vehicles forming the Renard train would be detached, picked up by the travelling crane and dropped into the railway wagons standing at the siding. By such means perishable goods could be got to market very quickly without resort to the clumsy and time-absorbing practice of throwing or shovelling everything out from the road vehicles into the railway trucks. Such a system would immediately give railway companies an opportunity of reducing rates. The carriage of agricultural produce would be one of the great fields open to the Renard train especially when acting as a feeder to railways.

When a comparison was drawn between light railways and road traction, there was a point which seemed to be always forgotten. It was that in road traction they were dealing with what one might call "house to house" delivery; whilst on a light railway they had to carry the produce first to a station on the light railway, and then to take it from that station on to the trunk line, and thirdly to deliver by horse haulage from the terminal station to the market.

Mr. Edwin Henwood said that he fully approved of the Renard system. There were many places which were without railway communication, the produce of which could be far more effectively brought into the towns for consumption, by the Renard train, than it was at the present time. There was a very important point which should be considered, and that was the right system for absorbing vibration. The outside of the wheel was not the right place at which to put the resilient material. Even authorities in this country said that the rubber tyre was pressed into the macadamised road, and, as it was relieved from pressure, it sucked up the road surface, and left a rut behind it. Therefore, the Local Government Board were very much concerned to find a resilient wheel having a wooden tread or tyre which would not injure the road surface. In resilient wheels, it was quite possible to put 300 or 400 cubic inches of rubber, always cushioning the axle so that the increased comfort of passenger would be very great. If they took the cubic content of rubber employed as twin tyres—at the point of impact with the road—on the back wheel of a motor-bus, assuming that two tons was the weight on the axle, it might be fairly said that the amount of rubber compressed did not exceed 4 cubic inches or thereabouts. Let it be taken at 8 cubic inches, and they would then get about 4400 lb. weight into 8 cubic inches which gave 560 lb. pressure per cubic inch on the rubber. If they had 400 cubic inches of rubber inside the wheel, they would reduce the weight upon the rubber inside, to the ridiculously small amount of 11 lb. per cubic inch; and, in addition to other advantages, they would get a resilient drive.

The authors stated that Colonel Renard fully considered the distribution of the load over three pairs of wheels as preferable to the usual method, with a view to the avoidance of stone crushing; but inasmuch as any good macadamised road was pressed into a fairly solid mass by a heavy road-roller, there need be no fear of pulverising the surface if a softer material—such as end grain timber—be employed on the tread of the wheel. By such means erratic side-slipping of heavy motor-cars might be largely, if not entirely, obviated.

Mr. W. H. Booth said that he wished to emphasise the remarks made with regard to the question of trailers. The legislation which limited road-trains to three vehicles was rendered necessary, simply because the ordinary drawn vehicle would run freely from one side to another and shake itself in pieces and shake the whole train in pieces at a very low speed; but, in the Renard train, that difficulty was entirely got over by the system of linkage which enabled the vehicles to follow one another with accuracy.

The transport arrangements of this country had three different aspects. There was the aspect of the main line to the railway; there was the aspect of the cross line to the railway; and there was the road aspect. For some years he saw a great deal of the road aspect of the country, and he found hundreds of spots which nobody knew anything about, or, at least, it appeared that nobody knew anything about them, and he himself had never known anything about them before. They were away on by-roads, such roads as could not be run upon by any heavy traction vehicle, and yet could be run upon by the Renard train. They were far away from the railways, and yet, all along those roads, there were entrances to farms. There was traffic to be got from those farms which would feed the railways for some distance and would also feed the small market towns which were scattered up and down the country.

Mr. W. Pollard Digby said that in their résumé of continental progress with regard to mechanical road traction, he thought the authors might have made some allusion to the Schieman system of railless electric traction, which did not involve the use of petrol or steam on the cars, but was a system of electric traction on roads without rails and without storage. It had the unfortunate drawback that two trolley wires, one for the positive and one for the negative lead, had to be carried over the road, and therefore a couple of trolley poles were required for the tractor vehicles. He had visited Dresden to inspect the Schiemen system running from Königstein up the Biela Valley. An omnibus with one electric motor was equipped with two trolley poles and dragged behind it certain trailer cars, taking up coal and raw material to the factories in the valley, and bringing back the finished product.

That system seemed to him fairly full of promise where the traffic was sparse and irregular. Of course, where heavy loads arose, it would be necessary to add a specially prepared track for an electric traction system. The defects of the Schieman system would therefore be its somewhat inelastic nature. One or two other installations had since been attempted, in particular one in Westphalia. In the installation at Königstein the electrical energy was obtained from a small waterfall with storage batteries to take heavy rushes of current upon starting. So far as he could ascertain, he believed that the energy consumption per ton-mile hauled would be about double that of a well laid tramway track.

As to the Renard road-train, he would ask the authors whether the rotated longitudinal shaft with its universal joints was an absolutely essential feature. Why should they not use a petrol engine to drive a dynamo on the tractor vehicle, and electric motors for the trailer vehicles, with control from the driver's seat on the leading wagon? It would then seem to be possible to maintain the articulated mechanism of the Renard train, and, in place of the central shaft with its universal joints, employ flexible electric cables conveying the current to motors on the driving axles of the six-wheeled trailer vehicles.

Mr. George A. Goodwin said that he should like to mention a point relative to the question whether the law, as it at present stood, would allow the Renard train to be worked, when it contained more than the prescribed number of trailers. He did not think that it was a question at all as to whether the system worked perfectly or not. After the remarks of Colonel Crompton, he took it that the train would keep in alignment, although, as he had not seen it, he could not quite understand the action. He did not think that the train would be allowed on public highways, unless the law was amended. Several speakers had admitted that, if in running along a road, one of the wheels of the driving axles got into a hole or slippery place so that it did not get a hold, then one of the vehicles at the back would push it forward. Now, if that hole was under one of the driving wheels of one of the rear vehicles, then the front ones would certainly pull it, and, under those conditions, the rear vehicles would be trailers for the time being. The question consequently arising was, "When is a trailer not a trailer?" While the answer was, "It was not a trailer when one set of driving wheels on a front vehicle was not gripping the road."

Mr. Thwaite, in reply, said that the discussion had been so prolonged that it was impossible for him to do justice to it in a verbal reply in the time left at his disposal. He would therefore send in a written reply to the secretary. There were, however, a few points to which he would reply at once. He agreed with Mr. Worby Beaumont, that the road question was an important one. It was so when our country was under the domination of Romans, and when Napoleon, who simply followed the Roman state system, was in power, he also made the road question an important and national one, and from his day, engineers in France had made roads which everybody admired. There was no problem of back to the land in France. He considered that the question of roads was not a local question at all, but one of national importance. Roads ought to be nationalised, but if they were nationalised, would it not be a duty to adopt a vehicular system which would do justice to them? The Renard system was the most serious attempt to do justice to the adhesive quality of the roads. The traction system with its heavy weights and wheels was about the worst possible system for the roads, whether they were bad or good ones. The better the roads, the better should be the vehicles using them. That was an axiom of road maintenance.

Another point was the differentiation between the trailer and the Renard unit propulsion system. The Renard system was not a trailer system, and he did not think that the Highways Acts would apply to it. The trailer system had been explained by Colonel Crompton. It was a non-vertebrate system—a system without a backbone. The trailer waggled about all the time, but in the unit self-propulsion or Renard system they had a rotative backbone which guided the train, and that differentiated it.

The following reply was subsequently received from Messrs. Thwaite and Thorp :—

The entire tendency of the present stage of the evolution of the mechanical system of mechanical road transport, is in the direction to justify the formation of special roads for motor methods of transport, and Mr. Thwaite's scheme of trunk motor ways formulated several years ago, appears to be within range of practical initiation.

We are glad Mr. Beaumont confirms the importance of Heilmann's pioneer invention. Dr. John Hopkinson thought highly of it ; it has certainly intrinsic merits that are well worthy of the serious attention of Students of Railway transport science, and its adaptability to the electric drawing of railway coaches and wagons constitutes a claim for, at least, experimental application, as an alternative to line electrification.

As regards road construction, in the future, more justice will be done to the elastic and waterproofing qualifications of dehydrated tar. With this agent and a suitable method of application there should be little difficulty in effecting the construction of a perfect road.

Certainly in some applications the Renard train may serve as a pioneer for a railway, and the railway companies will be quick to realise its value in this respect. The first cost of a light railway service will be at least ten times that of a Renard service, besides, if the traffic resulting proves numerically insufficient to secure financial success, the train can be removed to other spheres of usefulness. Whereas with a railway or tramway such a contingency would be disastrous.

A serious study of the British and Irish railway system will demonstrate that there are scores of missing links which the Renard system is well adapted, to filling up, to the advantage of both the public and the railways. Sir John Macdonald in his remarks emphasised, the fact of the high railway traffic burdens of our commercial community. Unfortunately the incubus of pioneering enterprise, the excessive cost of land, the parliamentary and illegal costs, and the safety regulations of the Board of Trade have all combined to make the cost of our railway systems exceptionally heavy, the Renard system will, however, help the agricultural areas in the matter of traffic economy.

In reply to Colonel Crompton, the authors would observe that the opinion of road surveyors on the effect of traction engines was pretty well known long before the advent of the car; and the effect of the pneumatic tyre on road surfaces, disturbed by the impact of the horses' hoofs is, and has been for a long time, the constant subject of discussion and complaint by road surveyors and rural authorities, so that the authors must be pardoned for holding to their opinion that the cry of the road surveyors for the protection of the roads is prompting legislative action. The authors are interested in the statement by Colonel Crompton that our roads are not kept in such a good state of repair as in the old coaching days. The clear differentiation of the Renard train from the ordinary trailer system, should prevent any future misconception.

Mr. H. S. Foster's remarks are very instructive. The authors recognised from the first how valuable the Renard road transport system would prove to be in coupling up the market towns of agricultural areas to the railways that were not served, partly owing to the opposition of many of the landlords in the pioneer days of railways. As Mr. Foster remarks, the Government in framing the Acts regulating road traffic had no knowledge of a mechanical road-train transport system with a sequence of self-propelled wagons, steered with the perfect control of a single vehicle.

Mr. Sennet's remarks are very pertinent. The suggested detachable frame will probably be adopted, where practicable, in connection with the application of the Renard system as a feeder for railways. The house-to-house delivery facilities possessed by the Renard system is an advantage of great commercial importance. In this connection, Mr. W. H. Booth's remarks relating to the highways and byway road communications to our farms, flour mills, etc., are very instructive.

In reply to the remarks by Mr. Pollard Digby, the authors would observe that the railless electric road motor has not been overlooked by them, but, as pointed out, the inelasticity of the system is one disadvantage, and the imperfect steering is another. Besides, an Act of Parliament would practically be required for permission to erect the electric transmission lines. The suggestion to adopt electrical unit propulsion *plus* the Heilmann principle as the actuation, and in combination with the Renard-Sourcouf steering gear has already received the consideration of the authors, and it certainly constitutes one of the possibilities of the system.

Mr. Goodwin's remarks are not surely meant to be taken seriously. Certainly, if both the rear wagon driving wheels ran into a hole, then for a second the rear wagon would be trailed, but then, and for a second, it would be the only trailer in the train, because, if the drivers of the other wagons ran into holes they would not be trailers, because they would be impelled by the rear wagon.

The following communication was received from Mr. Francis G. Bloyd subsequently to the reading of the paper :—

I thoroughly agree with the statement contained in the opening sentence of the paper, but I am not altogether in accord with the authors' opinion that the problem would be solved by providing an economical and rapid method of road transport between the towns and the land, because I fear this very means of transport would in many cases defeat the object in view. It would be far more likely to tempt the country labourer to seek work in the town, where higher wages naturally prevail, rather than induce the dwellers in the town to find employment out in the country. I suggest, therefore, that it would have been better to have based the need of improved means of transport on somewhat broader grounds, say, as a means of feeding existing carrying agencies, or of enabling dwellers in outlying districts to reach the larger centres of population.

Reference is made to a paper on canals read by Mr. Thwaite before the Society in 1905, a paper which I had the pleasure of hearing, also of taking a part in the discussion thereon. In that paper, Mr. Thwaite expressed the opinion that the progress of canals, as transporting mediums, had been seriously checked, if not altogether killed, by the policy of railway companies, and in the present paper the authors advance the view that railway companies have adopted a similar policy against mechanical road transport. I do not, however, agree with that view.

The Act for the construction of the first passenger railway in England, the Liverpool and Manchester line, was obtained in 1826, and the railway was opened in 1830. Road locomotives were first introduced about the year 1827, but according to the paper, regular road services were not organised until 1831. At that time, stage coaches were running on every main road in the country, and in my opinion it was rather the opposition of the proprietors of the coaches, coupled with the inability of the legislature of that time to frame regulations that would work with fairness towards the users of both steam and horse-power on the highways, that caused the practical adoption of steam transport to be abandoned.

The progress made since that date has been outlined in the present paper in a very interesting manner. I think the authors are perhaps a little too hard on the Act of 1865 (termed the "Red Flag Act"), as in the interests of the public some special legislation was certainly required.

Turning to the Renard and Sourcouf road-train described in the paper it appears to possess many advantages over other systems, especially with respect to the distribution of the motive power and the weight of the train over the road. It does not appear to be definitely stated what the exact load per axle is, and it would be interesting if the authors would furnish some information on this point, which is of some importance as to the probable wearing effects on the road and more especially with respect to bridges passed over.

As is well known, the recently issued regulations of the Local Government Board, issued under the Heavy Motor Cars Order 1904, enables the owners of bridges to restrict the passage of motor cars over them which exceed a gross weight of 5 ton. or which have an axle load of over 3 ton, that is, of course, if the bridges are not capable of carrying more than the weights stated—and it would seem to be essential that for a road-train to be really successful the gross and axle loads of the cars should not exceed those weights.

In reply to Mr. Bloyd's communication, the authors would observe that that gentleman must have misunderstood the opening sentence of the paper. It was never suggested that a rapid transport service, *per se*, would encourage the urban population to migrate and settle in the rural districts. The contention is, that if by means of a fast and cheap transport system the English farmer is placed on a more even footing with his foreign competitor, he will be able to make farming in England more profitable, and will thus be in a position to pay better wages, and give more regular work to the farm labourer, and thus induce him to stay on the land, instead of migrating to the towns, where he is not required, and only serves to swell the already large body of unemployed. The authors did not suggest that the railways had adopted a policy to the disadvantage of mechanical road transport, but that the railway mania had caused the subject of mechanical road transport to be forgotten or neglected. The authors, on the contrary, think that the railways will be greatly benefited by a good road transport system, and that, for their own sakes, they will encourage it, where likely to act as a feeder to their main lines. The maximum axle load of a vehicle of the Renard train, designed to carry a paying load of 4 ton, will be 2 ton, and the gross weight of such a vehicle, with its paying load, will be 6 ton. If the paying load is reduced to 3 ton, the maximum axle load will be 1 ton 14 cwt.

THE RENARD AND SOURCOUF ROAD-TRAIN SYSTEM.

BY B. H. THWAITE AND R. F. THORP.

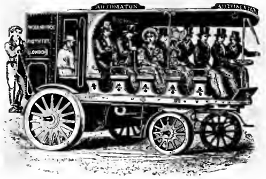

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FIG. 1.

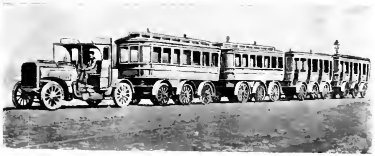

FIG. 2.

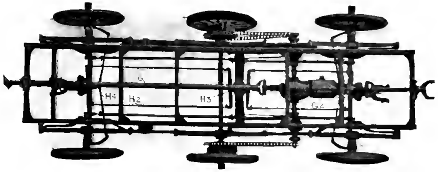

FIG. 9.

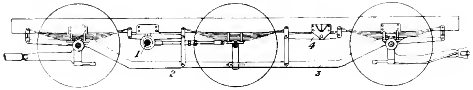

FIG. 3.

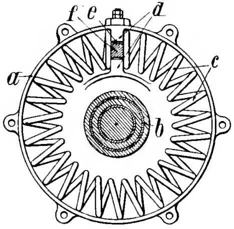

FIG. 6.

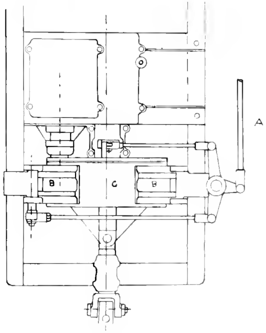

FIG. 10.

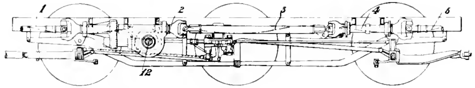

FIG. 4.

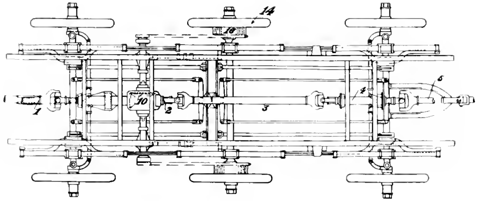
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FIG. 5.

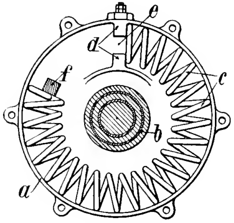


FIG. 7.

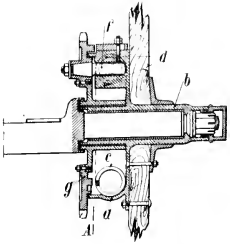


FIG. 8.

May 6th, 1907.

JOSEPH W. WILSON, VICE-PRESIDENT,
IN THE CHAIR.

WATERWORKS CONSTRUCTIONS IN AMERICA.

By ERNEST ROMNEY MATTHEWS.

INTRODUCTION.

THE author has been in communication with some engineers in America, respecting the methods adopted in that country in the designing and carrying out of various waterworks constructions, and he has received from them much valuable information relating to this important subject. This he has pleasure in giving in the present paper. As most members of the Society are well acquainted with the methods adopted in reservoir construction in this country, some having had a large experience in engineering work of this nature, the author does not intend to make comparisons between the British and American methods of construction, but to describe in detail how our professional friends across the Atlantic design and carry out works of this class. With this in view, he will first give a description of some reservoir works designed by Mr. Frank L. Fuller, C.E., of Boston, U.S.A., and carried out under his supervision; and the author would here acknowledge his indebtedness to that gentleman for his kindness and courtesy in furnishing him with the information here given respecting these interesting works.

The works designed by Mr. Fuller and described are: (1) The covering in of the Natick, U.S.A., reservoir, accompanied by plan and section (Fig. 1), and a detailed statement of cost. (2) The construction of a small covered distributing reservoir at the Franklin, U.S.A., Waterworks, accompanied by plan and and section (Fig. 2), and a detailed statement of cost. Other reservoirs of this type have been designed and constructed in America by Mr. Fuller.

THE NATICK RESERVOIR.

The works were commenced in August 1902, and completed in May 1903. The water supply of Natick was obtained from Dug Pond, a tributary of Lake Cochituate, which is situated about a mile from the town in a south-westerly direction, and thence it is pumped into a large reservoir situated on Broad's Hill, in the eastern part of the town. The water supply was introduced in 1874, and until recent years this reservoir was an open one, but was a source of continual expense, owing to its having to be so frequently cleansed, due to the bottom not being cemented. It was at times in a filthy condition, owing to the growth of weeds, which also gave the water an unpleasant taste. The slopes were paved, but were a constant source of trouble, and serious leakages occasionally took place. In 1890 the reservoir was repaired and enlarged; this was done by direct labour. The old slope paving, which was chiefly of small stones, was removed to within about 5 feet of the bottom, and used in building a core wall through the reservoir embankment. The new paving consisted of granite blocks 12 inches wide by about 7 inches deep by about 18 inches in length, laid on 5 inches of broken stone placed upon the old bank. The embankment at this time was raised 2 feet, and high-water level 3 feet 6 inches.

Previous to this enlargement the maximum depth of water allowed in the reservoir was 14 feet, which reached a level of 3 feet below the top of the embankment. After the embankment had been increased in height the maximum depth of water was increased to 17 feet 6 inches, and reached a level of 1 foot 6 inches below the top of the embankment. The original paving at the bottom of the slope for a depth of 5 feet was found to be in fairly good condition, so it was pointed with cement and allowed to remain. The core wall was built by excavating a trench near the centre of the embankment, and filling it with the stones laid in mortar composed of cement and sand. This wall was 8 feet in height by 2·5 feet in thickness at the bottom by 1·5 foot at the top. Its top is 1·5 foot below the new top of the reservoir embankment, and it extends 1·5 foot below the old surface at that point. The new granite paving extended to the top of the embankment. The inside dimensions of the reservoir at the top are 217 feet by 212 feet, the bottom being 159·8 feet by 154·3 feet. The area now covered in is therefore 44,730 square feet. The capacity of the reservoir before covering, with a maximum depth of water of 17·22 feet, was 4,340,000 gallons. With the same high water it is now 4,280,000 gallons.

In 1902, owing to the insufficient supply obtained from Dug Pond, and the pollution of this source of supply, it was decided to secure a new supply, and 150,000 dollars was appropriated for this purpose. This included the building of a new pumping station; the installation of a new high-duty pumping engine; laying a new 18-inch cast-iron force main to the reservoir, and covering a part or the whole of the existing distributing reservoir. Tests were made by Mr. Percy M. Blake, C.E., and these established the fact that a supply of ground water, sufficient for the needs of the town, could be obtained upon land already owned by the town, and situated on the borders of Lake Cochituate. This source of supply was adopted; and the now almost universally recognised necessity of storing ground water in covered reservoirs made the addition of a covering to the existing open reservoir almost imperative—it was decided that this should be done.

Piers and Roof.—It was decided to construct the roof of groined elliptical arches in concrete, and the specifications were so drawn that alternative prices were invited for brick and concrete piers. The lowest tender was that of Mr. F. A. Snow, and was for piers in concrete, 9.50 dollars per cube yard, and in brickwork, 14 dollars per cube yard. Concrete was therefore adopted. There were 169 piers in all constructed, and these were spaced 15 feet 2 inches apart, centre to centre. The reservoir being not quite rectangular, the piers were arranged so that the four lines bounding the outside of the system of piers formed an exact square 183 feet 5 inches on each side.

The dimensions of the piers and their foundations were as follows. The foundations are 3 feet by 3 feet by 1 foot 6 inches in depth, the top of the foundations being level with the underside of the 4 inches of concrete which now covers the bottom of the reservoir. The reservoir bottom has a uniform slope towards the centre of 1 foot. The first section above the pier foundations is 2 feet 4 inches by 2 feet 4 inches, the height varying from 1 foot 6 inches to 2 feet 6 inches, the tops of the sections being all on the same level. The second section, which is carried up for a height of 1 foot 6 inches, is 2 feet by 2 feet. The third or top section, which is carried up to a height of 12 feet 6 inches, is 1 foot 8 inches by 1 foot 8 inches. In the four outer rows of piers the foundations are of greater dimensions.

The Roof.—The covering of this reservoir, as already mentioned, consists of concrete elliptical arches, which have a span of 13 feet 6 inches and a rise of 2 feet 9 inches, and the arches are 6 inches thick at the crown, while there is a depth of concrete of 3 feet 3 inches over the piers. The top of the concrete roof is level with the average top of the slope paving.

Materials.—The concrete used in these works was 7 to 1, composed of 1 part cement, 2½ parts sand, and 4½ parts of screened gravel. The sand was coarse, clean, and sharp, the gravel was from the same pit, and of excellent quality. The concrete was mixed by hand, and was quite wet. A mixing platform was erected at the top of the embankment at the southwest corner. The minimum time allowed for the casing or shuttering to be removed from the piers was four days, but generally it was allowed to remain longer. The concrete for the roof was usually put on in sections 30 feet 4 inches wide, the joint occurring along the crown of the arch. A 6-inch by 6-inch spruce timber was laid along this line, and the concrete left flush with its upper surface. The roof centres were allowed to remain a minimum time of ten days after the concrete had been put on.

A certain amount of excavation was necessary at the bottom of the reservoir and the material excavated was thrown by successive lifts to the roof and spread over the concrete so as to prevent the latter from setting too rapidly. The concrete roof was subsequently covered with filling to a depth of 2 feet. A few fine cracks appeared on the upper surface of the concrete, generally over the piers. This was due to a slight settlement and also to slight contraction, owing to very cold weather occurring immediately after the completion of this roof, the thermometer dropping to 10° below zero. In no case were the cracks thicker at the surface than a penknife blade, and they entirely disappeared just below the surface. They were filled with liquid grout, and were not noticed again.

Reservoir Bottom.—The bottom of the reservoir was covered with 4 inches of concrete, finished off with cement rendering. On the completion of the work the bottom and sides of the reservoir were thoroughly washed by means of a stream of water from a fire hose attached to a connection in the bottom of the reservoir, water being furnished by direct pumping. The dirty water flowed off at the centre of the reservoir through the new 8-inch waste pipe.

Forms and Centres.—The forms for the lower sections of the piers were of 2-inch spruce plank planed on the inside, the grain being horizontal. Those for the long section of the piers were also of 2-inch spruce plank, the grain in this case being vertical. Planks 10 inches and 12 inches wide were used. On the front of each side a 2-inch by 3-inch piece was secured, extending the full length of the form. As the concrete was placed in these forms, great care was taken that the coarser material was kept away from the sides of the forms. The concrete was so wet that it needed little ramming. To resist the outward pressure of the concrete the forms were clamped by short pieces of joist tied together by iron rods having nuts and washers.

The centreing for the roof between any four piers consisted of four quarter sections. The frame was of one length of 3-inch spruce plank 10 inches wide by 13 feet 6 inches long, together with two pieces of 2-inch plank supported by the first-named piece and forming a sort of truss; also two side-pieces of 2-inch plank and two ribs of the same thickness. This frame was lagged with 1-inch matched spruce, planed on top. The quarter sections referred to could be easily handled by 4 or 5 men. The centres were brushed over with oil prior to the concrete coming in contact with them so as to facilitate their removal.

No derrick or hoisting engine was used for any part of the work, everything being done by hand. The number of roof centres used was 185; if the entire roof had been centred at once and no centre used twice, 624 quarter sections would have been required in addition to special centres necessary between the regular quarter sections and the inside slopes of the reservoir. The load on the piers was between 18 and 19 tons to the square foot at the bottom. After the roof had been completed two horse tip-carts well-loaded were driven across it.

Cost of Works.—In his report as to the total cost of these works, dated February 1904, Mr. Fuller gives the following particulars:—

	Dollars.		£	s.	d.
492·5 cubic yards of earth excavation from bottom and for piers in slopes, at 0.75 dollar	369.37	=	75	8	3
3103 cubic yards of earth excavation, borrowed from reservoir lot, at 0.75 dollar	2,327.25	=	475	2	11
130·6 square yards slope paving removed and replaced, at 2.50 dollars	326.50	=	66	13	2
239 cubic yards of Portland cement concrete on bottom, at 8.50 dollars ..	2,031.50	=	414	15	3
406·4 cubic feet Portland cement concrete in piers, at 9.50 dollars	3,860.80	=	788	4	11
1437·6 cubic yards of Portland cement concrete on roof, at 12.50 dollars ..	17,970.00	=	3,668	17	6
2647 square yards Portland cement finishing coat on bottom, at 0.75 dollar	1,985.40	=	405	7	0
Total	$28,870.82		£5,894	9	0

The cut through the reservoir embankment and the laying of the 18-inch force main into the reservoir, and the laying of the

Date when Constructed.	Location.	Engineer.	Description of Works.	Depth of Earth Cover.	
				ft.	in.
1895	Ashland, Wis. ..	Wm. Wheeler.. ..	Filters, net area half acre. Intrados elliptical, extrados plane, two layers flat brick backed with concrete.	2	0
1896	Somersworth, N.H.	Wm. Wheeler.. ..	Two filters, total net area half acre. Intrados elliptical, extrados plane, one layer of brick on edge backed with concrete.	2	6
1897	Wellesley, Mass. ..	F. C. Coffin	Reservoir, 80 ft. internal diameter. Intrados elliptical, extrados plane.	2	0
1898	Louisville, Ky. ..	Chas. Hermany ..	Reservoir, 154,739 sq. ft. net area. Concrete reinforced with steel. Intrados and extrados segmental.	0	6
1899	Concord, Mass. ..	Leonard Metcalf ..	Sewage reservoir, 57 ft. internal diameter. Intrados elliptical, extrados plane.	2	6
1899	Albany, N.Y. ..	Allen Hazen	Filters, 8 beds of 0·7 acre each. Intrados elliptical, extrados conical.	2	0
1899	Clinton, Mass. ..	E. P. Stearns	Sewage reservoir, 100 ft. internal diam. Intrados elliptical, extrados plane.	4	6
1899	Superior, Wis. ..	Allen Hazen	Filters and reservoir, total net area, half acre. Conical.	2	0
1901	Philadelphia, Pa., Lower Roxborough	John W. Hill	Filters, 5 of 0·537 acre each. Also filtered water basin, 153 ft. by 190 ft.	2	0
1902	Milford, Mass. ..	Leonard Metcalf ..	Filters, 2 of one-eighth acre each. Intrados elliptical, extrados parabolic	1	6
1902	Philadelphia, Pa., Upper Roxborough	John W. Hill	Filters, 8 of 0·7 acre each. Also filtered water basin, 238 ft. by 319 ft.	2	0
1902	Natick, Mass. ..	Frank L. Fuller ..	Reservoir. Intrados elliptical, extrados plane.	2	0
1903	Ithaca, N.Y.	Allen Hazen	Basin and reservoir. Intrados elliptical, extrados parabolic.	2	0
1903	Proposed for Lawrence, Mass.	Morris Knowles ..	Filter. Intrados elliptical, extrados parabolic.	3	0
1903	Yonkers, N.Y. ..	Allen Hazen	Reservoir. Intrados elliptical, extrados parabolic.	4	0
1903 Begun	Watertown, N.Y.	Allen Hazen	Basin and Reservoir. Intrados elliptical, extrados parabolic.	2	0
1903	Brookline, Mass. ..	F. F. Forbes	Reservoir, all concrete. Intrados elliptical, extrados plane.	2	0
1903	Philadelphia, Pa., Belmont	John W. Hill	Filters, 18 of 0·74 acre each. Intrados elliptical, extrados parabolic.	2	0
1903	Philadelphia, Pa., Belmont	John W. Hill	Filtered water basin, 382 ft. by 396 ft. Intrados elliptical, extrados parabolic.	2	0
1903 Begun	Philadelphia, Pa., Torresdale	John W. Hill	Filters, 33 of 0·75 acre each. Intrados elliptical, extrados parabolic.	2	0
1903 Begun	Philadelphia, Pa., Torresdale	John W. Hill	Filters, 22 of 0·75 acre each. Intrados elliptical, extrados parabolic.	2	0
1903 Begun	Philadelphia, Pa., Torresdale	John W. Hill	Filter water basin, 602 ft. by 762 ft. Intrados elliptical, extrados parabolic.	2	0
1903 Begun	Washington, D.C.	Col. A. M. Miller ..	Filters, Nos. 1 to 24	2	0
1903 Begun	Washington, D.C.	Col. A. M. Miller ..	Filters, Nos. 25 to 29	2	0
1903	New Milford, N.J.	Hering and Fuller..	Clear water well under Mech. filters. 2 sec. 47 ft. by 148 ft.	none	
1903	New Milford, N.J.	Hering and Fuller ..	Ditto ditto	none	
1903 Begun	Washington, D.C.	Col. A. M. Miller ..	P. W. Reservoir	2	0

Concrete Mixed.	Arch.									
	Span.		Rise.		Thickness at Crown.	Depression over Pier, in inches.	Pier Section at Springing, in inches, and Area, sq. ft.	Mean Thickness of Roof, in inches.	Pier Load, tons per sq. ft., above Springing line. Concrete at 150 lb.; Brick at 130 lb.; Earth, 110 lb.; Snow, 15 lb.	Intrados R = $\frac{(\text{Span})^2}{8\text{ Rise}}$	Intrados R = $\frac{(\text{semi span})^2 + (\text{rise})^2}{2\text{ Rise}}$
	ft.	in.	ft.	in.	in.					ft.	ft.
1 : 2½ : 5	15	9	3	6	6	none	28 × 23 = 4·42 28½×24 = 4·73 brick	11·7	12·5	8·9	10·6
1 : 2½ : 5	16	0	4	0	6	none	34½ ×34 = 8·15 granite	13·0	9·7	8·0	10·0
1 : 2½ : 5	12	0	2	6	6	none	24 × 24 = 4·0 brick	10·3	8·9	7·2	8·5
1 : 2 : 4	19	0	3	9·6	6	27·6	Dia. 3·4 = 9·0	11·7	5·8	(11·9)	(13·8)
1 : 2 : 5	12	9	3	0	6	none	24 × 24 = 4·0 brick	11·0	11·7	6·8	8·3
1 : 3 : 5	11	11	2	6	6	6	21 × 21 = 3·06 brick	8·5	11·0	7·1	8·4
1 : 2½ : 4	12	0⅞	2	6	12	none	30 × 30 = 6·25 25 × 25 = 4·33 brick	16·8	12·2 17·7	7·3	8·5
1 : 3 : 5	12	0	2	6	6	6	20 × 20 = 2·77 brick	8·4	12·0	7·2	8·5
1 : 3 : 5	14	0	3	0	6	21	22 × 22 = 3·36	7·3	13·3	8·2	9·7
1 : 2½ : 5 1 : 3 : 5	14	0	3	0	6	18	24 × 24 = 4·0	7·9	9·8	8·2	9·7
1 : 3 : 5	14	0	3	0	6	21	22 × 22 = 3·36	7·3	16·8* 13·3	8·2	9·7
1 : 2½ : 4½	13	6	2	9	6	none	20 × 20 = 2·77	10·2	15·1	8·3	9·7
1 : 2⅓ : 4½	10	6	1	6	6	10¼	18 × 18 = 2·25 17 × 17 = 2·01	6·78	10·9 12·2	9·2	9·9
?	13	2	2	9	6	18	22 × 22 = 3·36	7·5	15·6	7·9	9·2
1 : 2·9 : 5	10	0	1	6	6	9¾	16¾ × 16¾ = 1·96	7·0	18·5	8·3	9·1
1 : 2·9 : 5	10	0	1	6	6	10	18 × 18 = 2·25	6·9	9·9	8·3	9·1
1 : 2 : 4	12	0	2	6	6	none	20 × 20 = 2·77	10·1	12·2	7·2	8·4
1 : 3 : 5	13	5	3	0	6	2	22 × 22 = 3·36	7·3	12·4	7·5	9·0
1 : 3 : 5	14	0	3	0	6	21	22 × 22 = 3·36	7·2	13·3	8·2	9·7
1 : 3 : 5	14	0	3	0	6	21	22 × 22 = 3·36	7·2	13·3	8·2	9·7
1 : 3 : 5	13	2	3	0	6	21	22 × 22 = 3·36	7·4	12·0	7·2	8·7
1 : 3 : 5	14	0	3	0	6	21	22 × 22 = 3·36	7·2	13·3	8·2	9·7
1 : 2·9 : 5	12	2	2	6	6	17	22 × 22 = 3·36	7·3	9·7 + sand stored	7·4	8·6
1 : 2·9 : 5	11	10	2	6	6	17	22 × 22 = 3·36	7·4	9·1 + sand stored	7·0	8·2
..	9 by 11	8 8	2	6	8	none	24 × 24 = 4·0	11·7	..	4·7 6·8	5·9 8·1
..	11 by 12	8 0	2	6	8	none	24 × 24 = 4·0	12·3	..	6·8 7·2	8·1 8·4
1 : 2·9 : 5	15	6	3	6	6	24¾	30 × 30 = 6·25	7·9	8·7 + storage	8·6	10·3

* Including sand stored upon roof.

10-inch and 8-inch waste-pipe, was done partly by town help and partly by contractor at cost plus 15 per cent. These two items making the total expenditure on reservoir 30,116.75 dollars, or 6,148*l.* 16*s.* 8*d.* High water is now 17·22 feet above the bottom at the outer edge, and the capacity to this elevation is 4,280,000 gallons. The cost of covering the reservoir was about 2*s.* per square foot.

GROINED ARCHES FOR RESERVOIRS.

Mr. Leonard Metcalf, Civil Engineer, of Boston, U.S.A. (Past President of the New England Waterworks Association), has prepared some valuable data relating to groined arches which have chiefly been constructed in connection with reservoirs and filters in the United States, and which information he presented to the Association in 1903. The author is indebted to Mr. Fuller for a copy of that statement, which includes the Natick reservoir roof, and is shown on preceding pages.

THE FRANKLIN RESERVOIR.

The object of this reservoir, which has recently been completed, is to store a supply of water which will flow by gravity to the old pumping station on Bow Street, Franklin, where it can be pumped by water power to the old reservoir in Pleasant Street. The reservoir (see Fig. 2) is 46 feet in diameter and 20 feet deep. Each foot in depth contains 12,431 gallons, or a total of 248,600 gallons for a depth of 20 feet. The side wall is 3·5 feet thick at the bottom, 2·5 feet at the top, and 22 feet high, except at the point where the 12-inch inlet and outlet pipe and the 6-inch overflow and waste pipe enter the reservoir, where it is deeper.

Construction.—This wall is built of boulder concrete, that is ordinary concrete into which stones have been rammed of a size not greater than can be lifted by one man. The proportions were 1 of cement, 2 of clean sharp sand, 4½ of screened gravel, all by volume, to which was added 40 per cent. of sound, clean boulders or field stone. The boulders were not allowed to come within 6 inches of the face of the wall, and no boulder was allowed to touch another.

The roof is 10 inches thick at the springing, and 8 inches thick at the centre, and has a rise of 4·6 feet. To resist the thrust of the roof, a steel band 14½ inches wide and 1 inch in thickness, is embedded in the concrete near the top of the concrete wall. It is made of two thicknesses of ½-inch by 14½-inch plates, each about 26·7 feet long. These were put in place of breaking joint, and with two cover plates (one ¼ and one ½ inch thick) riveted together. This band was furnished by a firm at Boston, and by them riveted together on the wall when it had reached the proper elevation. The price of the band in place was 338 dollars. After the steel band was in place, the concrete wall was continued to the springing line of the roof. The band is thus completely enclosed in concrete, protecting it from corrosion.

The centreing for the roof was then set up, and on November 20, 21 and 22, 1905, the concrete roof was put in place. The wedges supporting the timbers at the centre of the reservoir were removed on December 5, and the entire centreing removed a few days thereafter. No cracks or settlements in the wall or roof have been observed. The wall, where necessary, was pointed with cement mortar, and received several brush coats of neat cement and water, mixed to the consistency of thick paste. The bottom is of 6 inches of Atlas cement concrete, the upper half-inch being without coarse material, left smooth, and well trowelled. The 6-inch overflow and waste pipes are arranged substantially as in the old reservoir.

A small wooden house (4 feet 6 inches by 6 feet 6 inches inside), is placed over the 30-inch opening in the concrete roof, and an iron pipe ladder extends from the bottom of the reservoir to the opening in the roof. An electrical indicator shows at the Bow Street pumping station the elevation of water in the new reservoir. A 6-inch Ross Valve Co.'s balanced valve, with float attached, placed in the pump well of the Bow Street pumping station, automatically closes when the water in the pump well reaches high water level, and stops further inflow from the new reservoir, thereby preventing waste.

The following particulars are taken from the tender for the Franklin reservoir, which was accepted.

FRANKLIN COVERED RESERVOIR.

Name of Firm Tendering.	1200 cub. yds. Earth Excavation.	Cub. yds. Rock Excavation.	380 cub. yds. Am. Portland Cement Boulder Concrete in Wall	50 cub. yds. Am. Portland Concrete Roof.	20 cub. yds. Broken Stone on Bottom.	200 lin. ft. 3-in. Drain-Pipe on Bottom.	30 cub. yds. Am. Portland Cement Concrete on Bottom.	50 lin. ft. 12-in. Pipe Laying.	100 lin. ft. 6-in. Pipe Laying.	100 lin. ft. 4-in. Pipe Laying.	Cub. yds. Borrowed Earth (if required.).	Sq. yds. Sodding.	Total Amount of Tender.
Savage Concrete Construction Company, New York.	$0.48 = 756.00	$5.00	$5.98 = 2272.40	$8.00 = 400.00	$3.00 = 60.00	$0.05 = 10.00	$5.50 = 165.00	$0.40 = 20.00	$0.30 = 30.00	$0.25 = 25.00	$0.26	$0.27	$3558.40 or £726 10*s.* 1*d.*

COVERED RESERVOIR AT LOUISVILLE.

This reservoir is a good example of a modern American covered reservoir, constructed throughout in reinforced concrete, including division walls and piers, and of which Fig. 3 shows one bay. The roof is of the groined-arch method of construction, the arches being approximately 19 feet span and 3·8 feet rise, the radius of the arc forming the intrados being 13·775 feet, and that of the extrados 32·256 feet. The thickness of concrete at the crown of arch is 6 inches, and above piers 3 feet. The reservoir is 460 feet by 392 and 394 feet in size, and has a capacity of 25,000,000 gallons. The columns or piers are about 3·4 feet diameter and 21·11 feet in height, and are placed 22 feet apart, centre to centre. The whole of this interesting construction has been carried out in Portland cement concrete 1 : 2 : 4.

Embedded in each of the arches are $1\frac{1}{2}$ by $\frac{5}{16}$-inch steel ribs, resting upon each pier. These ribs are inserted in eight half-piers; four of these are placed at the groins of the arch, and four midway. Two steel plates, 16 inches square by $\frac{5}{16}$ inch thick, are placed in each pier, and in the side division walls of the reservoir, and the ribs meet upon and are riveted to these. The plates are placed $28\frac{1}{4}$ inches apart vertically, tied together in the middle by a $\frac{1}{2}$-inch rivet. In order to make sure that the steel ribs adhered to the concrete, $\frac{3}{8}$-inch rivets were placed through the middle of the rib about every 12 inches apart.

The author is indebted to Mr. Charles Hermany, engineer of the Louisville Water Company's purification station at Crescent Hill, Kentucky, for the following detailed account of the Louisville reservoir:—

Design.—The design was decided upon in 1898, and the work was completed in 1900. Both the arches and columns are stronger than necessary, were they only to support themselves and the earth filling. This has been proved by building upon the groined arches a concrete bed 8 inches thick over the crown, in which a track is built of standard steel rails, 80 lb. to the yard, and loaded freight cars pushed over it with a combined dead and live load (car and freight) of five tons to the car-wheel, without visible effect upon arch or columns. When designing these arches it was not apprehended that it would be desirable or necessary to run cars across them. Great misgiving was manifested by contractors as to the practicability of building reliable columns of this description. The successful and satisfactory building of them proved to be one of the easiest and simplest tasks connected with the reservoir. The concrete was machine-mixed, but all the manual labour was performed by crude and unskilled men, with which difficulty was experienced in satisfactorily building the arches. It was accomplished only by constant and vigilant engineering supervision. With the experience gained in this work, entirely satisfactory results could be obtained, with reduction in both volume of concrete and cost of construction. The solidifying of the concrete by tamping was done by hand, in layers of about 4 inches in thickness at a time. Better results have since been accomplished by reducing the thickness of layers and using pneumatic tampers.

Area Covered.—The following gives the area of water surface roofed over by the groined arches :—

	Square feet.	Square feet.
Total area of quadrangular space covered by the outside dimensions of the structure		180,740
Area covered by the four retaining walls . .	18,541	
Area covered by the three division walls . .	4,460	
Area covered by the 256 columns supporting the groined arches	3,000	
Aggregate area of water surface in the four compartments	154,739	
Total . . .		180,740

The groined arches are 340 in number, 270 of which are square, 22 by 22 feet span between centres of columns, and seventy arches are in one direction of 22 feet span, and at right angles thereto of variable span—both greater and smaller than 22 feet—owing to the quadrangular plan of the reservoir not being a square, but a trapezoid.

In the following table are given the items which comprise the cost of constructing the arched covering to the clear-water reservoir, subdivided into ten different classifications of material and work.

	Per sq. ft.
1. 2446·93 cub. yds. Portland cement 1 : 2 : 4 concrete in columns at \$7.10, $\frac{\$17,373.20}{154,739}$	\$0.112
2. 333·32 sup. yds. Portland cement, 1 : 2 mortar, in columns, at 29 cents, $\frac{\$96.66}{154,739}$	0.001
3. 7484·11 cub. yds. Portland cement 1 : 2 : 4 concrete in arches, at \$7.10, $\frac{\$53,137.18}{154,739}$	0.343
4. 978·13 sup. yds. Portland cement 1 : 2 mortar in arches, at 42 cents. $\frac{\$410.81}{154,739}$	0·003
Carried forward . .	\$0.459

	Per sq. ft.
Brought forward	\$0.459
5. 168,750 lb. steel ribs in concrete arches, at 3¼ cents, $\frac{\$5,484.40}{154,739}$	0.035
6. 7325·89 sup. yds. neat Portland cement mortar ⅛ in. thick plaster on columns, at 23 cents, $\frac{\$1,684.95}{154,739}$	0.011
7. 18,444·87 sup. yds. neat Portland cement mortar ⅛ in. thick plaster on soffit of arches, at 23 cents, $\frac{\$4,241.40}{154,739}$	0.027
8. 3,928·04 cub. yds. earth fill over arches, at 30 cents, $\frac{\$1,178.41}{154,739}$	0.008
9. 154.739 sup. ft. sodding, at 10½ cents per sup. yd., $\frac{\$1,805.29}{154,739}$	0 012
10. Centres for arches, and falseworks, $\frac{\$9,000.00}{154,739}$	0.059
	\$0·611
Less correction	0.001
Total cost per square foot of covering	\$0.610=2*s.* 6*d.*

In the foregoing, items 2 and 4 are for mortar used to interpose between successive additions of concrete, so as to make such additions adhere to each other. The ten items of cost comprise the total amount paid by the water company to the contractor, to which has to be added the cost of inspection and engineering supervision.

Covered Reservoir at Rockford, Illinois.

An interesting example of a covered reservoir built with an arched roof is that which was constructed at Rockford, Illinois, U.S.A., in 1894, a transverse section of which is shown in Fig. 4. The reservoir is 156·56 feet by 66·26 feet. Only the roof is of reinforced concrete. The roof is a ribbed arch, the ribs increase in depth from crown to haunches, and are placed 7 feet apart. The section shows in detail the arrangement of the reinforcement. The concrete used was 1 : 2 : 5, and the soffits were plastered with 1 Portland cement to a 2½ sand mortar. This reservoir cost \$18,506 or £3778 6*s.* 2*d.*, the roof alone costing \$2000 or £408 6*s.* 8*d.*

Before leaving the subject of reservoir construction, the author would state that the most recent American practice is as follows:—

1. There is a growing use of the groined arch as a covering for reservoirs and filters in America.

2. A depression is made in the concrete roofing over the piers, as at the Louisville reservoir, which is considered to effect a saving of from 15 to 30 per cent. in the cost of the roof. In constructing the roof over the Philadelphia filter plant with a depression over each pier of 21 inches, a saving of 2·7 cubic yards of concrete was effected at each pier, or a saving of over 30 per cent. It is usual to fill the depressions with clay puddle

3. The section of piers is considerably less than formerly.

4. The introduction of reinforced concrete is a marked feature in recent reservoir and filter construction.

5. Circular piers as at the Louisville reservoir with square capitals are a new form of construction, and it has been found that these can be built at the same price as square piers; if nothing else is accomplished by the introduction of these, a more equal distribution of material is obtained.

REINFORCED CONCRETE GRAVITY DAM AT THERESA, N.Y.

The following is a description of a very interesting form of dam which has recently been constructed at Theresa, N.Y., and which is illustrated at Fig. 5. It is built in reinforced concrete, and is an entirely new departure in dam construction. It was designed by Messrs. Ambursen and Sayles, of Watertown, N.Y. It is 120 feet long by 11 feet high, and has a foundation on the solid rock. It consists of a concrete slope supported by concrete buttresses, the former being 6 inches in thickness and the latter 12 inches in thickness, and placed 6 feet apart centre to centre. The whole is reinforced by ¾-inch Thacher steel rods and expanded metal as shown in the cross section.

The buttresses and toe are of Portland cement concrete 1:3:6, and each buttress was bolted down to the rock by 3 feet 1¼ inch bolts. The dam is so constructed that the resultant pressure always falls within the base.

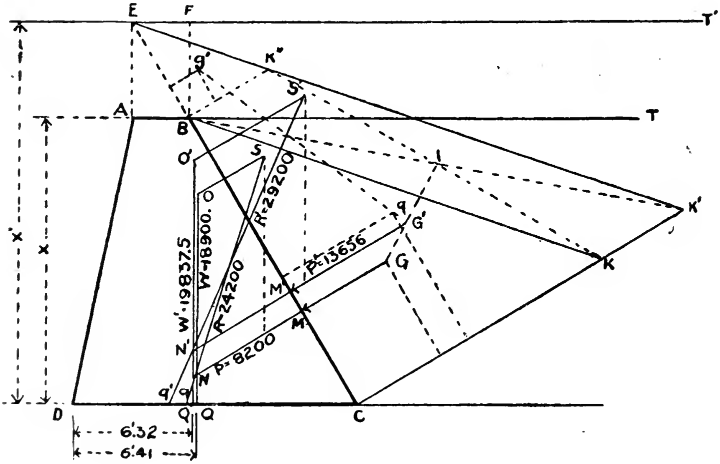
GRAPHIC SOLUTION.

The graphic solution of the forces acting on a dam of the type just described, as used by most American engineers, is given as follows by the author, who is indebted for it to an American work on reinforced concrete by Mr. A. W. Buel:—

"The graphical method of finding the pressure on the immersed surface of a dam, the overturning moment, and the resultant on the base is illustrated in the accompanying figure.

"Let B C be the immersed surface, D C the base, B T the surface of the water, and x the depth of the water. Draw C K perpendicular to B C and equal to x, then will the weight of the water in the prism B C K, of a length unity, be the amount of the pressure on the immersed surface one unit in length. This pressure, P, will act normal to the surface B C, and through the centre of gravity of the triangle B C K at G, and will intersect B C at M, C M being equal to one-third of B C.

"Find the centre of gravity of the section of the dam D A B C and its weight, W. From the intersection of P with the vertical through the centre of gravity of the dam at N, lay off N O equal to the weight W, by the scale of forces, and draw O S parallel to N G, making O S equal to P by the scale of forces. Then the resultant on the base, R, will be represented in direction and amount by the line S N, and its intersection with the base at q will be the centre of reactions on the base.



"If q is found within the middle third of the base the dam will be in stable equilibrium, provided the maximum intensity of pressure on the foundation is not excessive. The intensity of pressure on any part of the base may be found by the method given for retaining walls, using the vertical component of R acting through q. When the immersed surface is vertical the methods given for finding the thrust on retaining walls are applicable by making ϕ equal to zero.

"When the crest is submerged the solution will be as follows: Produce the line B C to intersect the surface of the water at E, and lay off C K′ equal to x' and perpendicular to E B C. Draw B K″ perpendicular to B C from the crest of the dam and find the centre of gravity of B K″ K′ C. This may be done by locating the centres of gravity of the triangles E C K′, B C K, and E B K″ at *g*, G, and *g*′ respectively and that of the parallelogram B K K′ K″ by the intersection of the diagonals at I, then the centre of gravity of B K″ K′ C will be at G′ and G I intersects *g*′ *g* produced. Or if on *g*′ *g* produced, *g* G′ is laid off equal to *g*′ *g* multiplied by the area of E B K″ and divided by the area of B K″ K′ C, G′ will be the centre of gravity sought. The area of B K″ K′ C is the difference of the areas of the triangles E C K′ and E B K″.

"The centre of gravity of a right-angle triangle is at the inside corner of a rectangle, the sides of which are one-third the length of the sides of the triangle adjacent to the right angle, the rectangle being inscribed in and including the right angle of the triangle.

"A force equal to the weight of B C K′ K″, for a length unity, acting through G′ normal to B C at M′ will be the resultant pressure P′ on a unit of length of the surface B C.

"Find the weight W′ of a unit of length of the section of the dam and the prism of water A E F B, over the crest, and the intersection of the vertical through the common centre of gravity with P′ at N′, and lay off N′O′ vertical and equal to W′. Draw O′S′ parallel and equal to P′, then S′N′ will be the resultant R′, intersecting the base at *q*′.

"The values of P, W, R, and the distance D Q and P′, W′, R′, and the distance D Q′, given in the accompanying figure, were found by assuming the following dimensions and unit weights.

x = 15 feet.
x' = 20 feet.
The base D C = 15 feet.
The batter of A D = 3 feet in its height.
The crest A B = 3 feet.

"The average weight of the prism of the dam = 140 lb. per cubic foot, and the weight of water = 62·5 lb. per cubic foot. For P, W, R, and D Q, the water level is at A B T, and for P′, W′, R′, and D Q′ the surface of the water is at E F T′."

PROVIDENCE FIRE SERVICE MAIN.

The author is indebted to the ex-City Engineer of Providence, U.S.A., Mr. Edmund B. Weston, M. Inst. C.E., for the following particulars of a special high pressure fire service main which he has laid in the city of Providence (see Figs. 6, 7 and 8). The laying of the pipes was commenced in September 1896 and completed in October 1897. This main consists of 4189 feet of

24-inch main, 23,004 feet of 16-inch main, and 2216 feet of 12-inch main: total 29,409 feet.

To these pipes are connected eighty-nine hydrants, the static pressure at which ranges from 116 lb. to 85 lb. per square inch, according to the elevation of the hydrant. The sizes of the pipes are such that under ordinary conditions the pressure will not fall below 100 lb. per square inch in the centre of the business portion of the city when 5,000,000 gallons per twenty-four hours or 3472 gallons per minute are being drawn from the pipes. Arrangements have been made so that in the future, if it should be desired, a stationary pumping plant can be connected to the pipe, and the pressure raised 50 lb. more per square inch than the pressure is at the present time. At a test in Exchange Street, a stream of water being discharged at a rate of about 950 gallons per minute from a 2½-inch ring nozzle, reached a vertical height of about 137 feet.

The pipes of the new high pressure fire service were laid 6·25 feet deep, which is about 1·6 foot deeper than the depth of the ordinary water pipes, in order to pass under the water pipes and other obstructions that were already in the ground, as well as a precaution against the freezing of the water in the pipes of the fire system, which will be more likely to occur on account of its comparative stagnation. As an additional safeguard against freezing, a by-pass has been located between the high and low service and three blow-offs connected at convenient points, all of which are supplied with gates which are opened more or less in freezing weather, and a circulation produced throughout the entire fire service system.

The three special features about this high pressure fire service main are: (*a*) The special design of the joints, (*b*) the manner of securing the pipes where laid on the curve, and (*c*) the manner of securing branch pipes. These special features are illustrated in Figs. 6, 7 and 8. Fig. 6 shows the method of securing the curved pipe of the high pressure fire service. Fig. 7 shows the method of securing the branch caps of that service, whilst at Fig. 8 is shown the special joint for the high pressure main.

The author has now placed before his fellow members information concerning the latest American practice in certain branches of water engineering, which he hopes may prove both interesting and useful. Interesting as affording means for a comparison to be made with English practice, and useful as conveying information which may possibly prove instructive in certain directions.

DISCUSSION.

The **Chairman** said that it was his privilege to ask the meeting to pass a vote of thanks to the author of the paper. He had brought forward some interesting information, including prices, some of which might seem to be unusual, judging from work in this country. He thought they might form a subject worthy of a certain amount of discussion; as it was not always easy to get prices in such papers. There were some interesting applications of ferro-concrete illustrated in the plates, and, although the paper was not specially on that subject, there was no reason why the discussion should not deal with it. Fig. 5 showed an interesting application of ferro-concrete slabs with expanded metal; of which he (the chairman) had recently seen some remarkable examples in this country. The author referred in his paper to the certainty that steel rods embedded in concrete would never corrode: perhaps someone present would be inclined to allude to that point. English engineers were always ready to benefit by papers relating to American practice.

The vote of thanks was carried by acclamation.

Mr. R. E. **Middleton** said that they ought to be very much obliged to the author for his paper, as it was of the utmost importance that English engineers should study the practice of other countries. It was exceedingly difficult to arrive at a definite conclusion in pounds, shillings, and pence, as to the value of English practice as compared with American, because the cost of materials and labour differed so greatly in the two countries. The peculiarities which the paper brought to their notice were specially the use of cylindrical columns of concrete instead of rectangular ones of brick, and the use of large span reinforced arches and groining instead of barrel arches. His own practice in constructing reservoirs of the character described in the paper had been to use concrete except for the facing of the inside of the reservoir He had not used shuttering except for the roof. He had employed 4½-inch blue or glazed brickwork with about ten headers to the square yard for the walls which were built up three bricks high and filled in at the back with concrete of the thickness required. He had found those reservoirs both exceedingly cleanly in appearance showing up the water brightly, and thoroughly water-tight. The floor was made of concrete alone, floated over with Portland cement grout. With regard to the roof he almost invariably made it of concrete jack arches supported by longitudinal steel joists laid on cast-iron columns. The latter cost rather less than brickwork and took up less room. The jack arches were 6 inches thick at the crown. The level of the haunch was lower than the crown by about 18 inches. Many of the figures contained in the paper were not comparable with that practice. For instance, they could only compare the covering of the Natick reservoir with the covering of any other reservoir. The covering of one of the reservoirs to which he had referred cost 11*s.* 7*d.* a yard. At the Natick reservoir the cost was 17*s.* 10½*d.* At the Franklin reservoir it was 16*s.* 4*d.* At the Louisville reservoir it was 14*s.* 8*d.*, and at the Rockford reservoir it was only 5*s.* 11*d.* That seemed a very low price for a reservoir of that character. If the columns had been included, the cost of the first or English one was 13*s.* 9½*d.*, and of the Natick 1*l.* 1*s.* 9*d.* The Franklin reservoir had no columns. The Louisville reservoir cost 18*s.* 7*d.*

The Antwerp reservoir, which was reinforced, cost per thousand gallons 2*l.* 15*s.* 9*d.*, the Rockford 3*l.* 4*s.* 10½*d.*, and the Franklin reservoir 2*l.* 18*s.* 5½*d.* The first reservoir of which he had spoken in this particular case was also about a fourth of the size of that at Antwerp and cost about 4*l.* 10*s.* per thousand gallons. The Antwerp reservoir which had a capacity of about two and a half million gallons was the cheapest of all.

A little while ago he had to construct a reservoir exactly like those he had described as far as the roof was concerned, and it had to go before the Local Government Board. The engineer suggested that it was an entirely new departure, but he (Mr. Middleton) told him that he had used a similar construction at the Forth Bridge 23 years ago, and also that he had put another reservoir of about the same size in the same place 17 years ago, with similar steel joists. The engineer to the Local Government Board feared the joists would rust. He (the speaker) was able to have the reservoir emptied shortly afterwards, and he examined the steel girders, they were barely touched with rust on the underside where exposed to vapour from the water after 17 years.

With regard to the use of ferro-concrete generally for purposes like reservoirs where there was considerable exposure to damp he was very doubtful whether it would last. Ferro-concrete was a somewhat new thing. He had seen cases where the steel had rusted after a short time. On the other hand he had found cases where the steel had been absolutely bright. In the first case damp must have penetrated to the steel reinforcement, in the second there must have been a movement both in the concrete and in the steel which tended to their destruction. He was sure armoured concrete might be used economically and with great advantage in large warehouse floors and in places where no damp was likely to come. In all probability the piles which had been used in several cases with reinforcement inside them would last at any rate for a great number of years, though if concrete alone was used without any reinforcement and carried down as had been suggested in a steel case to be afterwards removed, the same result, he believed, would not be obtained without danger of destruction from rust. He constructed some concrete piles some years ago somewhat after that fashion by driving in wooden piles and withdrawing them, and then filling up the space with concrete, and the result had been extremely satisfactory. Of course, in some places where there was water and ferro-concrete piles had been used, that would not be applicable, but the system in which the concrete was filled into a steel casing, which was afterwards withdrawn, leaving the concrete free without possibility of any rusting taking place, would be safer than any system which combined both concrete and steel. He had looked into the cost of reservoirs constructed of ferro-concrete, and he believed that similar reservoirs could be constructed of concrete alone at the same cost. That, of course, meant that they would allow a considerably greater thickness of concrete than where reinforcement was used. In one case, they had practically a homogeneous mass, and in the other they had, at any rate at present, a somewhat mixed material.

With regard to what the author of the paper had said about fire-mains, he did not quite understand why such precautions had been taken about a main that had only 100 feet head of water. He put down some fire-mains some years ago, into which the water had to be pumped, as there was no water supply sufficiently high to force the water through the fire-hose up to the roofs of the buildings which had to be protected. If there was a fire, the supply was cut off, and the pumping engines were connected directly with the mains. The mains were simply ordinary quality cast-iron pipes with lead joints. The water was thrown to a height of about 120 feet.

He had hoped that he should have heard something from the author as to the difference of construction of impounding reservoirs in England and America as well as of service reservoirs. The American practice was, in many cases, very different from the English, and, with due deference to American engineers, he thought that it was inferior to the English. English engineers preferred to use puddle for the centre of an earthbank, and Americans generally used concrete or rubble. The bank was always moving, more or less, and both concrete and rubble were liable to be fractured by the movement, whereas clay adapted itself to the movement. There were other conditions of construction which were different from those in this country, and it would be of the greatest interest to English engineers, if the author would direct his attention to them and give some particulars in a future paper.

Sir EDWARD RABAN said that, although he had not come prepared to discuss the paper, he might make one or two brief remarks on what Mr. Middleton had said. Mr. Middleton had told them that, for certain purposes, simple concrete piles might be preferred to reinforced concrete, and he was inclined to agree with him ; but there were many cases in which they had to use piles and in which they wanted something of the elasticity which was got from the reinforcement of the concrete. It might be possible and even probable that reinforced concrete was not an absolutely permanent thing, yet, for sea work, it was a material so infinitely more permanent than the ordinary timber pile, and as it resisted the action of the teredo and other marine organisms, it was well to put in ferro-concrete, even though it might not be absolutely permanent. It had the advantage—and this he was able to speak of with some little experience—that it would resist the impact of heavy ships bumping against it in a way that a concrete pile would not. There were other cases also in which reinforced piles had their virtues for exactly the same reason.

He was also struck with another remark made by Mr Middleton, and he took it very much to heart indeed, because he thought that everyone should take to heart everything that Mr. Middleton had told them. It was that, on the whole, Mr. Middleton was of opinion that all concrete reservoirs could be made as cheaply as reinforced concrete. He (Sir Edward Raban) thought that that must depend very much on local conditions, and, indeed Mr. Middleton had stated so at the beginning of his remarks. It would depend upon whether they had the materials for good concrete in the locality of the work. Mr. Middleton had told them how difficult it was to compare the price of English work with American work, because the rates of labour and transport and all kinds of other things varied very much. They had in the paper the fact that, in more than one case, no machinery was used at all, and that the labour was all hand labour ; and, then, they were told again that it was exceedingly unskilled labour, and that it was only with the greatest personal attention on the part of the engineering staff that they were able to get the work done at all. For those reasons, he thought that it was unsafe to lay down as a general rule that they could carry out work more cheaply in all concrete than in reinforced concrete. He believed that there were cases where it must be true that reinforced concrete was cheaper, and, probably better than all-concrete. No doubt, there were other cases in which a much simpler form of construction would be both cheap and efficient.

Mr. Percy Griffith said that they would all agree that a comparison between English practice and that of other countries was very useful. He would endorse Mr. Middleton's suggestion that the author should extend his researches, and give the Society on some future occasion a paper upon other branches of engineering practice in America. The author had brought before them several interesting points of comparison between British and American methods of construction, although the author disclaimed the intention of making any such comparison. When American practice was described, one rather expected to hear of something which was subversive of prevailing ideas and practice in this country. He did not, however, find anything in the paper of a very startling character, or which was not, more or less, familiar to English engineers.

The most interesting and important point to which the author drew attention was reinforced concrete, and he noticed that the example referred to was a dam where the construction practically represented a flat surface supported on buttresses where the stresses on the intermediate spans corresponded to those on an ordinary reservoir roof, or very nearly so. That, he thought, did not altogether illustrate the most interesting construction to which reinforced concrete could be applied. Most English water engineers were so far converted to the use of reinforced concrete that, under reasonably suitable circumstances, they would be disposed to use it very readily.

Another important point to which the author drew attention was the use of groined arches. That applied to three or four of the examples quoted by the author. He thought that others would join him in asking the author wherein lay the advantage of a groined arch, by which, of course, he understood an arch which was arched in both axes. A simple arch with one axis appeared to meet every possible need in the case of a reservoir or filter roof, supported, as it usually was, either on steel girders, or (if the Local Government Board inspectors objected to steel girders) on a wall, which could be arched or not, according to circumstances. They could secure a perfectly satisfactory construction with a single axis arch, and he could not at all comprehend why their brother engineers in America had seen fit to resort to the more complicated and more costly groined arch.

Another noticeable feature in the examples which the author had given was the mixtures of concrete. A proportion of 7 to 1 seemed to be the strongest mixture mentioned, and 9 to 1 was given in several instances. In that respect English engineers evidently differed from their American friends in their ideas about the strength of the work which they carried out. In the table of groined arch work, the average proportion of the concrete was 8 to 1. Of course, if one were absolutely regardless of the quantity of material to be used, those proportions were perhaps not so important, but in a construction where the strength of the structure was a matter for calculation, the English practice was safer, without being extravagant.

The principal point of interest about the Natick reservoir was that its roof had groined arches. He would suggest that the ordinary arch construction would have been cheaper and quite as efficient. There was, however, a small point of construction shown in the section of the reservoir on Plate I., which seemed to call for some explanation. He referred to the dwarf walls built in the reservoir banks, and called by the author "core" walls. In that connection, there was a somewhat mysterious reference to serious leakages which took place "occasionally." He could not quite understand how leakages could be "occasional," his own experience being that once they commenced they kept on, and became increasingly troublesome. He was a little puzzled to know how the "core" walls could prevent a leakage in the bank, unless they were carried down into the natural ground. He could only suggest that the explanation would be found in the nature of the subsoil upon which the reservoir was constructed. That introduced what in his (the speaker's) mind was a question of the utmost importance in comparing one form of construction with another. No useful comparison was possible, unless they knew all the local circumstances. One often heard engineers speaking about its being "their practice" to do so and so; but he had never yet been able to standardise his practice in regard to any particular form of construction, because he never found the local circumstances sufficiently alike in any two cases to justify the application of a standard design.

With reference to the Natick reservoir, the floor was shown as only 4 inches thick. There again they clearly met with the importance of local circumstances, and he expected that the explanation of that point was the same as in the previous case of the "core" walls, viz. that the foundation in both cases was remarkably sound and good, probably solid clay, which in the one case was used in the banks, and in the other enabled the floor to be made 4 inches thick, without reinforcement. The same question as to the subsoil arose with regard to the load on the piers, which, the author said, was between 18 and 19 tons to the square foot at the bottom. That showed that the subsoil must be pretty good. The table of groined roof structures was interesting, but he missed what would have been a most interesting column, namely, that of *l. s. d.*

The illustration of the Franklin reservoir presented a small point of some interest, namely, the fact that the washout pipe was laid at a curious angle right through the floor. One usually avoided the risk of breaking the continuity of a reservoir floor by keeping pipes clear of the floor and laying them in an independent mass of concrete. The question of groined arches arose again in connection with that reservoir; the real question of cost arising mainly in connection with the centreing. If reinforced concrete construction were adopted, it was the common practice to avoid an arch altogether and to have simply a flat slab about 5 inches thick, which had been found by experiment to stand enormous loads. In the present case the centreing was reduced to a minimum, consisting of nothing more than flat boards supported on scaffold poles. In that reservoir the floor was only 6 inches thick, and that again seemed to suggest a good sound subsoil.

In connection with the Louisville reservoir the author explained that the roof was made unnecessarily strong, and that the contractor was rather nervous of the test to which it was put. In this country engineers were generally more jealous of the *l. s. d.* than they were in America, and had to "cut their coat according to their cloth," it sometimes being a "tight fit." One really wondered whether the extra cost in the reservoir in question was justified. The cost of the Rockford reservoir appeared to have been very low indeed, and the explanation was not particularly clear. Possibly, the author might be able to tell them why the cost in that case worked out at 9½*d.* a square foot as compared with 2*s.* in the previous cases. The question of substituting clay for concrete in the haunching, was another point involving a knowledge of local circumstances, because if there was no clay in the neighbourhood it might be cheaper to use concrete.

With regard to the dam illustrated on Plate III., he would suggest that that design was not at all suitable for high dams such as were common in this country. He could quite appreciate the design being used in the case of a reservoir which was formed entirely by excavation, but not in the case of an impounding reservoir formed by means of a dam at one end. It was rather curious that the diagram given in the text of the paper was totally different from that given as a practical example, and he would like to know whether the latter fairly represented the practice to which the author was alluding, and of which the calculations were given.

As to the fire-service main described in the paper, at least 60 per cent. of the waterworks in this country supplied some parts of their districts with water at a pressure of 116 lb. per square inch, and they did not as a rule use bolts and nuts to hold the joints together, but relied upon ordinary lead joints. Of course, with pressures of 700 lb. per square inch for hydraulic power purposes bolted joints would obviously be necessary, but he could not see why they should be used for such a small pressure.

Mr. G. B. WILLIAMS said that it was very satisfactory to have information with regard to American works put before them in such a concise form as in Mr. Matthews's interesting paper. In one respect he rather disagreed with some of Mr. Griffith's remarks. He—the speaker—considered that in this country both in designing works of water supply and also sewerage works, there was a distinct tendency for English engineering practice to get into a groove. It was, therefore, very advantageous, even from the point of view of engineers whose work lay wholly in this country, to be occasionally reminded that there were other methods of construction than those with which they were familiar. On the other hand, those members of the profession who had to face engineering or sanitary problems in newer countries were glad to get any light that could be thrown on them by a description of recent American work.

In such cases the difficulty with which they had usually to deal was that they had a rapidly increasing population, generally of mixed nationalities, often living in the most unhealthy surroundings, with practically no form of sanitation at all, and generally with none of the conveniences of civilisation. Many engineering works were thus urgently necessary, while the amount of money which could be expended upon them was strictly limited, and engineers had to choose between doing the works in the most economical way possible, and not doing them at all.

He agreed with what had been said as to the advantage of having full details of cost set out in a paper of the present kind, as was done in this case. He noticed that English engineers in writing papers describing the works which they had done, often appeared to be chary of giving details of expenditure, as if the cost was a thing to be ashamed of (as, in fact, it very often was), but, after all, cost was the ruling factor in nearly all engineering matters, and descriptions lost nearly half their value when those details were omitted. He was interested and somewhat surprised to find how very great was the difference in cost between American and English work of the same nature. For instance, 50*s.* a cubic yard for concrete in an arched roof or 34*s.* for concrete in a floor were exceedingly high prices. They were about double what was paid in England for the same class of work.

Mr. Middleton had given them examples of prices of English work and compared them with the prices stated in the paper. He would also like to mention, by way of comparison, the cost of roofing a reservoir which had been recently constructed in this country. The reservoir was 86 feet long by 59 feet wide, and the greatest depth was 12 feet 6 inches. It contained about 350,000 gallons, and the roof was a 4 to 1 concrete roof with an average thickness of about 7 inches, supported by 6-inch by 4½-inch steel joists, placed 3 feet apart. They were supported on 14-inch longitudinal brick walls. The cost worked out to exactly 1*s.* 6*d.* per square foot. The roof was an exceptionally strong one, but the price compared favourably with most of the examples quoted in the paper.

He agreed that it would be interesting to have further details as to the subsoil in the Natick reservoir. A pressure of from 18 to 19 tons per square foot on a foundation 18 inches deep seemed to show a rather exceptional trust in Providence, which he hoped would be justified.

As to the Franklin reservoir, he would not like to see a large crowd of people assembled on the roof. Nor was there any special reason which one could see from the drawings why the reservoir should be water-tight. There was no lining of any kind, nor was there any facing of cement rendering. One would naturally suppose that it would leak like a sieve.

Generally speaking he thought that the examples were a little disappointing. There was nothing which one would feel very much inclined to imitate. The only exception was the round pier, which, after all, was a somewhat minor detail. The groined arches might or might not be a very good form of construction; but it was a fairly well known one, and was not confined to America. The idea of forming depressions over the piers did not strike him as being extraordinarily original, because it was what one would naturally do. The only thing necessary would be to arrange some method by which the depressions would be drained.

He did not quite understand what the author meant by saying that the concrete dam was an entirely new departure, because there were several other reinforced concrete dams in America, and some of them seemed to be of exactly the same type as those described in the paper. He should say that there would be a great deal of prejudice against introducing such a form of construction in this country. But there were places in the Colonies with which he was acquainted where, for the sake of economy, he would be prepared to build a dam of something of that nature, if occasion should arise.

He wished to ask the author a question which was suggested by some remarks made by Mr. Middleton, and that was whether there was in America any restriction or any control over the expenditure of local bodies exercised by a department corresponding to our Local Government Board. If not, American engineers would have an obvious advantage in the matter of economical forms of construction. At the same time there would not seem to be any protection for the inhabitants of the country in general, or the ratepayers in particular, against the results of vast experiments or inefficient or inexperienced engineering, such as—whatever its faults might be—was undoubtedly provided to some extent by the Local Government Board.

Mr. G. H. Hughes said that he appreciated the valuable remarks which Mr. Middleton made as to his own practice, and he must say that he followed on a somewhat similar line. He had never had a failure of that form of construction with steel joists and ordinary segmental or semi-circular arches. But one system which was very cheap in construction was to place between the steel joists, when spaced about 3 feet apart, corrugated iron bent to the radius of the arch, and not to use any centreing of timber whatever, the bottom flanges of the steel joists forming a support, and concrete being filled in between the joists. The corrugated iron was left in after the construction, and remained in. On examining the reservoirs several years after he found the roofs sound. He mentioned that as a very cheap form of construction. Besides, when using timber and shuttering, there was a risk of striking the timbering too early. He had seen reservoirs in which the concrete had fallen away, and the arches had cracked on that account. Through there being too much haste in striking the shuttering, there had been a little movement.

Another form had been simply a 4½-inch brick arch sprung from the lower flanges of the steel joists and the spandril spaces filled in with concrete, laid to a fall to drain the surface water from the top of the reservoir. He believed in all those cases the cost had come out at from about 1·25 shilling to 1·80 shilling per square foot, including the sheet iron and the joists.

One important point in considering the cost of reservoirs was the nature of the subsoil, the depth of the excavation, and the amount of material to be moved. That did not appear in the paper, but it was a very important feature in estimating the cost of a reservoir. Such a pressure as 18 to 19 tons to the square foot, referred to by the author, was extraordinary for ordinary soil. He should think there must be good rock bottom to carry that load. His practice had been to avoid more than 3 tons to the square foot, and he had sometimes reduced the pressure to 2 tons or even 1 ton. That point had been overlooked by some engineers.

He had recently to report upon a reservoir that failed. The excavations seemed good. They had been taken down to about half the depth of the reservoir, and the reservoir had a reinforced concrete bottom 11 inches thick. The concrete was 6 to 1, and the cement was good. Everything seemed to have been well done, but, when the reservoir was filled with water to a depth of 15 feet, the bottom collapsed, and the water ran away. On examination he discovered the cause; the bottom was formed of conglomerate rock bedded with clay and very soft material. There had been a failure, he supposed, in some part of the bottom where the water got out and washed a void, and the void increased. The reinforcement being only in one direction, the bottom cracked, and the water escaped. He went down a void, or swallow, 17 feet deep below the bottom of the reservoir.

That went to show that in the construction of a reservoir the first thing was to consider the nature of the ground before they could decide the material of which it was to be constructed and the dimensions. Of course, where sand and gravel were available, concrete construction would be much the cheaper form. In cases in which neither sand nor gravel was available, perhaps bricks would be the only cheap material to be had on the spot.

Mr. Middleton had referred to the 4½-inch brick lining of the internal walls, the back being filled up with concrete. That was a system of which he (Mr. Hughes) had also had experience, and he had found it very satisfactory and very cheap where materials were available. Perhaps to the top of a hill the cartage of timber and materials would be an expensive item, and much of that was saved thereby.

There was a point in reference to the reinforced dam to which previous speakers had not referred, and that was the joining of the Thacher bars Of course, the reinforcement of the concrete depended very much on the joints. The bars could not be got continuous in very long lengths, and round bars were not so easily riveted as flat bars. Could the author give any information as to the joining up of the longitudinal bars?

In reference to the Providence fire-main, he took it that the particular specially designed pipe-joints were only used where the mains were laid on a curve. In dealing with mains where the water was suddenly arrested; it had been his practice always to secure them by bands and bolts at curves and at dead ends. If a 4-inch hydrant on a 12-inch main was closed very quickly it would be liable to draw forward a short length of main, and it was very important either to secure the pipe on to the hydrant by having drilled holes through the socket into the pipe and set screws, or else by having a flat band and bolts, in a similar way to that described by the author, to prevent the joint blowing. He took it that all the joints were ordinary spigot and socket joints, because the section of the socket was shown on Plate III., and the stayed joints were merely to prevent movement.

There was a little misunderstanding, he thought, as to the pressure of 116 lb. per square inch. If they had a flow through several hydrants, it would be, he thought, a wise precaution to stay the curves. He had known 24-inch and also 18-inch mains where the joints had blown at curves in soft ground. Another remedy was to concrete around the outer radius of the curves between the mains and the trench to prevent movement of the pipes, and consequent "blowing" of the joints. In another case there were about ten miles of pumping main with a double-acting pump on it. Although the pressure was not nearly so heavy as the one which would start the joints, the vibration of the pump caused the joints to shift, and they had to be kept together by means of tie-bolts and straps, or more correctly, the lead joints were held in position by that means. He would add his appreciation of Mr. Matthews's paper, and the valuable details he had obtained and laid before the Society respecting recent American waterworks construction.

Mr. W. H. Holttum said that he thought the author might have given more information concerning the geological conditions in which the reservoirs and works were carried out. Without such data, it could not be determined whether they were to feel surprised, or not, at the great cost of the concrete. It might be that there was some reason why the concrete was such a price as quite appalled them, but there were things that they had learned; for instance, if they had concrete at that figure, they would have to look most carefully after the crude manual labour, and probably be brought to such economies as leaving little pocket holes to save the concrete, and to dumping boulders into it of a size that one man could lift, as referred to in the paper.

Reference was made in the paper to "a slight settlement and also to slight contraction owing to very cold weather," and it was also stated that, "In no case were the cracks thicker at the surface than a penknife blade, and they entirely disappeared just below the surface. They were filled with liquid grout, and were not noticed again." That was where the inspection did not seem to go quite far enough. He wished to know whether it might not have been noticed again, and that the cracks in the concrete had extended downwards. That was a point on which he should have been particularly anxious. The supervision of the work was, as already noted, a lesson to them all. Constant vigilance had been bestowed on it, and he would have been glad to have had some more detail of the resultant circumstances, which tended to reduction in both volume of concrete, and cost of construction. Those concrete roofings and floorings were liable to crack at about every 15 feet, and such cracks would be detrimental. There were cracks, but apparently they were not of a serious nature. In works of the kind under notice a "purpose" left straight jointing in slabs of from 12 to 15 feet square obviated unsightly cracking, and such joints could be left so as to receive satisfactorily the subsequent cement grout filling.

Mr. H. C. H. SHENTON observed that Mr. Percy Griffith said he saw nothing very new or surprising in the designs brought forward by the author; but Mr. Griffith appeared to have overlooked, at any rate, the Franklin reservoir, in which there was a retaining wall for water which was apparently backed by made earth 20 feet high and 3 feet 5 inches thick at the base. He did not think that many English engineers would care to put in a reservoir wall like that He had known the Local Government Board object to walls of much greater strength. He would like to know if the steel hoop round the top was the explanation of the extraordinary dimensions of the wall. That wall, as far as he could see, could not be trusted to support the water. He supposed that its circular form must be taken into account as making it strong enough to take the earth pressure, but he did not think a wall which had a maximum thickness equal to about $\frac{1}{6}$ of its height was strong enough to support ordinary earth pressure.

Another noticeable thing was that in one reservoir there appeared to be a floor 4 inches thick which was not reinforced in any way, whereas, in the Louisville reservoir, a floor 15 inches thick was shown where, as far as could be gathered, the foundation was soft, viz. clay puddle. It appeared to him that the engineer would have done very much better to rely on the reinforced concrete there, because he did not think that, if the foundations were soft, the 15 inches of concrete would not be enough to sustain the water pressure. That pressure was about 20 feet, and it looked very much as if a little reinforcement might have been put there with advantage. A 15-inch beam of concrete of large span resting on puddled clay with a load of 1240 lb. per square foot was poor work indeed. Then over that there was a roof 2 inches thick, apparently of reinforced concrete, but still very thin. He did not know what distance apart the ribs were, but 2 inches seemed to be too thin for anything.

He supposed that engineers in America had a very much freer hand than they had over here. They were probably not made to conform to any requirements of a Local Government

Board or authority of that kind. They could simply put in the most extraordinary structures, and, generally, they were successful. But, sometimes, they were not successful, and awful accidents happened in consequence. The English engineer had not a free hand, for instance, for one reason and another, he was hardly allowed to put in ferro-concrete at all. There was a great prejudice against it, and as some speakers had said, there was even an objection to the use of steel joints with concrete.

With regard to the water main, he endorsed what Mr. Griffith had said. He had seen mains taking a much greater pressure than those described in the paper without any special protection of the joint. As for the special design of the joints, it appeared to him that they were ordinary spigot and socket joints, and without any special feature unless it was the irregular inside surface of the socket. Then there was the remark made by the author that now it was almost universally recognised that ground water should be kept in covered reservoirs. He thought that it depended upon whether they were storage reservoirs or service reservoirs. If they were large storage reservoirs, he should say that they should be left open, partly because it would be very expensive to cover them and partly for the sake of purification.

With regard to the centreing for the concrete roof, he observed that the minimum time for the centreings to remain was ten days; and, apparently before that time had elapsed, while the concrete was setting, it was actually loaded with earth. He had seen the roof of one reservoir come down through being loaded too soon, and he should say that ten days was a very short time to allow. It was, he thought, very risky to load concrete with earth before the concrete was set hard, because the extra pressure coming on might easily cause it to crack and give considerable trouble later.

Communication received from Professor Henry Robinson, M. Inst. C.E., Past-President.

I consider Mr. Matthews's paper to be a most useful record of waterworks successfully constructed in America in which reinforced concrete has been employed, and the thanks of the Society are due to the author for a paper which will prove most useful for reference by all who have to design and construct similar works. I have given considerable attention to the employment of reinforced concrete and to the conditions that have to be complied with, both as regards calculations in designing structures, and the practical points that require to be strictly observed in their execution. England has been slow in recognising the advantages of reinforced concrete, but the system is now better appreciated than it was a few years ago, and Mr.

Matthews's valuable paper comes at an opportune time, and will help to ensure a recognition of the benefits accruing by adopting the system, as it enables works to be successfully executed under conditions which would involve great difficulties, or may even be impracticable without it, as was the case with a reservoir which I had to design.

Communication received from Mr. W. H. Maxwell, Assoc. M. Inst. C.E., Water Engineer, Tunbridge Wells.

Mr. Matthews's paper raises a very important question with which I am in practical touch at the present moment, viz. the necessity for storing ground water in covered reservoirs, and also mentions the unpleasant taste of the Dug Pond supply to Natick, which is stated to be "owing to the growth of weeds." Although an abundant growth of weeds may, upon decay, injuriously affect the water and lend support to much microscopic life therein, their presence does not, I think, necessarily explain the objectionable character of this water. These are matters which have been much more thoroughly studied in America than in this country, and many expert biologists are continually at work on that side of the Atlantic investigating the causes of disagreeable tastes and odours in water supplies, and much practical help is thus afforded to the water engineer.

From examinations of the Dug Pond water by the Massachusetts State Board of Health in 1901, it was found that this water contained microscopic organisms of kinds known to cause disagreeable tastes and odours in the waters of many ponds and reservoirs and that their presence was the cause of the trouble in this case. The Board consequently advised the abandonment of this source in favour of a new supply from underground sources. The organisms were most numerous in the months of May and November. A microscopical examination in November 1895, showed as many as 1990 organisms per cubic centimetre, 1660 of which consisted of the diatom *Melosira*, which is known to be the cause of a vegetable and oily odour in the water.

The new source of supply, completed in 1903, consisted of a well, 31 feet in diameter, and 21 feet deep, and the new covered reservoir described by Mr. Matthews, enables the water to be delivered to the consumers without exposure to light. This is a very important practical point, and any contribution, such as the present paper, supplying details, as it does, of new and economical methods of covering supply reservoirs, will certainly be heartily welcomed by water engineers, who will the more fully appreciate the importance of covering in their storage, as the true causes of tastes, odours, and deterioration of different classes of water become known to them. For these reasons I am of opinion that the water engineer should also be a biologist and microscopist so far as relates to the microscopy of drinking water.

In this connection I have recently had some troublesome experience in a 45-million gallon open storage reservoir owing to the rapid growth of the diatom *Asterionella.* So prolific was its development that the filter beds upon which this water was treated, repeatedly became surface choked within about one sixth of the customary period of work, thereby entailing an almost prohibitive cost for frequency of scraping and cleansing the top of the sand bed. To the untrained naked eye the presence of this diatom could not be detected, though present in vast numbers, but its detrimental effect in deranging the working of the filters was so marked as to seriously threaten the proper maintenance of the daily supply.

By means of a microscopical examination of the slight deposit from this water, I was able to identify the diatom causing the trouble, and, from experience and investigations since made, I find its growth to be due to the mixing with the spring supplies a proportion of deep well water, drawn from a depth of some 350 feet, the latter water containing the necessary food material for diatomaceous growths.

I have since found, in the course of my inquiries, that under very similar conditions, *Asterionella* caused serious trouble at Brooklyn, N.Y., and gave the water a disagreeable taste and odour. There, as in my own case, the construction of a by-pass around the reservoir had to be hastened forward in order to maintain an uninterrupted supply to the town.

The most certain remedy for all such troubles is the covering in, wherever possible, of storage reservoirs, or, where the main storage is too large for roofing, separate covered accommodation should be provided for the storage of underground water. The light armoured concrete structures dealt with in Mr. Matthews's paper, provide at once a convenient and economical form of roof.

Mr. E. R. MATTHEWS thanked the meeting for the cordial way in which they had received his paper. He was unable to answer many of the enquiries which had been made during the discussion, as he had not received information from the American engineers on the points raised. The works he had described were designed and carried out by American engineers, and not by himself. He totally disagreed, although the author of the paper, with many points in the design and construction which he had been describing. For instance, why the American engineers had gone in so much for the use of groined arches he could not say. He could not see that there was any saving in adopting that design. In fact, it appeared to him to be much more expensive. In his paper he was merely showing the American way of constructing works of that class.

It had been said by Mr. Middleton that they could not compare the cost of works of the class under notice in America with those of the same kind in England, and he quite agreed with that remark. The value of materials in America would be very different from that in England, and a comparison in that respect would not be at all fitting. It was, however, interesting to know the proportional cost of the various parts of works of that nature as given in the paper.

The particulars Mr. Middleton had given of the methods he adopted in reservoir construction would be useful to engineers. The Antwerp reservoir was a very cheap form of construction, and it appeared to be a very efficient one, and he would point out that reinforced concrete was largely used in the construction of that reservoir. He, however, disagreed with Mr. Middleton when he said that he thought that the use of reinforced concrete where there was damp, as in a reservoir, was a thing which engineers should be rather dubious in adopting, though it would be right to use it on warehouse floors, or anywhere where there was no dampness. He (Mr. Matthews) had, with the greatest advantage, used reinforced concrete in many situations where the works were continually coming into contact with damp, and he strongly advocated its use in such works. For piles and works of that class, reinforced concrete was, in his opinion, admirable; and it would be more generally adopted in this country, as in America, were it not for the fact that English engineers got into a groove, and nothing would move them out of it. Impounding reservoirs had been referred to by Mr. Middleton as having been passed by in the paper, but after to-night's discussion he should think seriously of preparing a paper on that subject.

Some of the questions asked by Mr. Percy Griffith he was unable to answer, for the reason already given. With regard to concrete, 7 or 8 to 1, he agreed with Mr. Griffith that, in all good practice in this country in connection with waterworks and reservoirs, they ought not to use concrete mixed in those proportions to form the bottom or walls of a reservoir. They might use it probably for roofing in, but not for any part which came in contact with water. At the Natick reservoir the subsoil was clay, and the reservoir bottom rested on a bed of clay. That, he supposed, accounted for the small thickness of covering forming the floor of the reservoir, which he agreed was very much less than would be adopted in English practice. He quite agreed that a load of 18 or 19 ton per square foot on concrete piers, even if they rested on clay, or even the solid rock, would seem to English engineers altogether unreasonable. Probably they would adopt about a quarter of that load.

As to the Franklin reservoir, he agreed with Mr. Griffith as to the peculiar position of the wash-out pipe laid diagonally on the floor. It was contrary to English practice.

With regard to the Louisville reservoir, the roof was unnecessarily strong, as pointed out in the paper, but the engineer who supplied him with the information about the reservoir had not said why that was so. With regard to the depressions over the piers, it seemed to him that, if concrete in this country cost 50*s.* per cubic yard, English engineers would follow the example of the Americans, and cause a depression to be made over every pier.

Some of the speakers had asked, whether in America there was any controlling board like the Local Government Board to regulate expenditure. The answer was that there was no such authority in that country, and, consequently, engineers had, to a large extent, a free hand. From some points of view that had many advantages. He thought that it would be better in this country, if engineers had a great deal more freedom in designing engineering works for local authorities, they would then have a better opportunity of launching out into more modern methods of construction. As they all knew, the Local Government Board got into a groove in the same way that engineers sometimes did, and they could not be got out of it; as an instance of that, the disfavour with which the Local Government Board had, until quite recently, looked upon the introduction to any large extent of reinforced concrete in engineering structures might be cited.

He agreed with Mr. Griffith that the form of the dam referred to in the paper would be altogether unsuitable for the high dams in this country. It was not intended even in America that that form of construction should be used for high dams. It was only for low buttressed dams, and for that purpose the American design was, he thought, very advantageous and effected a great saving of material.

With regard to the fire-service mains of Providence; as had been pointed out by Mr. Williams, the special strengthening of the joints by means of bolts, occurred only where curves occurred in the main. He thought that, even for what would be called a low pressure in this country, it would be advantageous for English engineers to adopt a similar course.

He agreed with the remark of Mr. Williams that English engineers were very chary as to adopting any new form of construction. The same speaker said that the depression over the piers, as in the Louisville reservoir, was not an original idea. But he (Mr. Matthews) did not think that he had seen that form of construction adopted previously. In saying that it was a new form of construction, he meant so far as this country was concerned. The same remark applied to the reinforced concrete dam.

Some interesting information had been given by Mr. Hughes respecting reservoir construction, and his own experience of that class of work. He was, however, unable to answer Mr. Hughes's enquiries with regard to the joining up of the Thacher bars.

Mr. Holttum said that it would add to the interest if they had some geological information as to the bottom of the various reservoirs; but he (the author) was unable to afford any information on the point in addition to what he had already given.

Attention had been drawn by Mr. Shenton to the light construction of the Franklin wall. He (Mr. Matthews) quite agreed that the Local Government Board would never have passed a structure of that kind. To English engineers it seemed rather too light. He also agreed with Mr. Shenton, with regard to the Louisville reservoir floor, that it would appear to us to have been better if reinforced concrete had been used instead of ordinary concrete. As to the roof of the Rockford reservoir, Mr. Shenton had referred to its being only two inches thick, and had asked as to the distance of the ribs. The ribs were 7 feet apart, so that the covering in consisted merely of a slab of reinforced concrete 2 inches thick, supported by the ribs, and seemed to answer the purpose very well. Mr. Shenton also said that he had seen mains with a greater pressure than those described, without any bolts having been used. He (Mr. Matthews) agreed with Mr. Shenton, he had also seen that.

With regard to the storage of ground water, when he said that it was now generally accepted that ground water should be stored in covered reservoirs, he should have said that it was generally accepted in America.

With respect to the two communications which had just been read, he agreed with Prof. Robinson that this country had been very slow in recognising the advantages of reinforced concrete. Mr. Maxwell deserved the thanks of the Society for the valuable information he had given respecting the Natick water supply, and the causes of the disagreeable tastes and odours found in the water.

Communication received from Mr. Thomas R. Smith, Assoc. M. Inst. C.E. waterworks engineer, Kettering, subsequently to the meeting.

The covering of the Natick reservoir is very similar to the usual reservoir covering in this country, except that the arches are groined instead of being formed in parallel lengths of segmental arching. The author does not state the reason of the adoption of the groined arch, whether it is found to result in a saving of material or labour, but at first sight there does not seem much saving in material when the upper surface is brought to one level as in this case, though, as he states further on, a saving of as much as 30 per cent. in the material of the roof may be effected by curving the upper surface so as to form depressions over the piers. The manipulation of the timbering hardly seems so simple as with the centreings and laggings of the ordinary construction, and if the roof work were constructed in brick arches, which was the alternative proposal for this roof, the groining would require a good deal of labour.

As regards the manipulation of the concrete, the author states it was so wet as to need little ramming. The use of moderately wet concrete with some ramming is a very usual practice to secure good solid work, and extra wet concrete, consolidating only by its own settlement, could hardly produce so good a result. General experience shows that the ballast of concrete will not of itself settle as closely and compactly as when moderately rammed in thin layers.

The construction of the wall of the Franklin circular reservoir with 40 per cent. of boulders in the concrete is somewhat unusual for walls averaging only 3 feet in thickness, and when the 6 inches on each side is deducted, the whole of the boulder work is confined to the central thickness of 2 feet. No doubt a considerable saving of cement would be made in this way, but, as a matter of construction, it could hardly be so strong as if made of a homogeneous concrete throughout. The use of the steel band, of course, relieves the wall of all thrust from the roof, and this reinforcement seems economical at a cost of only about 68*l*.

In the other two examples of reservoir construction reinforced concrete is introduced. In the case of the Louisville reservoir the reinforcement appears to have been introduced purely to give additional strength over and above that required for the covering, as the thickness of the concrete roof would seem sufficient for this purpose without the reinforcement, but in the Rockford reservoir we have purely reinforced work, full advantage being taken of the reinforcement to produce a light roof covering. The use of thin walls and roofs of reinforced concrete for tank work where lightness of construction is not material will, of course, be only a matter of cost, and so there may be no advantage in putting a thin roof covering to a reservoir which is afterwards to be covered with 2 feet or more of soil. But where this is not to be done, as apparently in the present example, and in all cases of water towers where the weight of the structure is a very important point, reinforced concrete is specially suitable.

Communication received from Mr. C. H. Priestley, M. Inst. C.E., waterworks engineer, Cardiff, subsequently to the meeting.

I have carefully read Mr. Matthews's paper, and there are a few points which struck me in connection therewith upon which to remark, not however by way of criticism, but merely to point out differences which appear to me most divergent from work which I have seen.

In the description of the Natick reservoir, there is mention of a core wall built near the centre of the embankment. I have tried to find out the reason for this wall, it being the first I have ever seen in such a position, but I am unable to ascertain for what reason it is built, and what good it is doing in the centre of the embankment in the position shown, unless it be to strengthen the embankment, and that does not appear to me to be necessary.

It is stated that "the now almost universally recognised necessity of storing ground water in covered reservoirs, made the addition of a covering to the existing open reservoir almost imperative." If this is so in America, where the conditions are different generally from what they are in England, the rule may apply, especially where great variations of temperature occur with intense frost. Personally, as far as my experience goes, I have found that open service reservoirs are preferable to covered service reservoirs, speaking generally, for storing water derived from drainage areas. This does not apply, of course, where it is likely that the water will be contaminated from smoke, coal dust or any such matters, near to or within the town, but where a service reservoir is situated outside the town and free from contamination through impure air, etc., I consider an open reservoir is to be preferred to a covered one. I built a service reservoir holding some three million gallons within about two miles of the city, some eight years ago, and there has never been the slightest difficulty with the water from dirt or smell, and no vegetation whatever has formed either within the reservoir or on the sides.

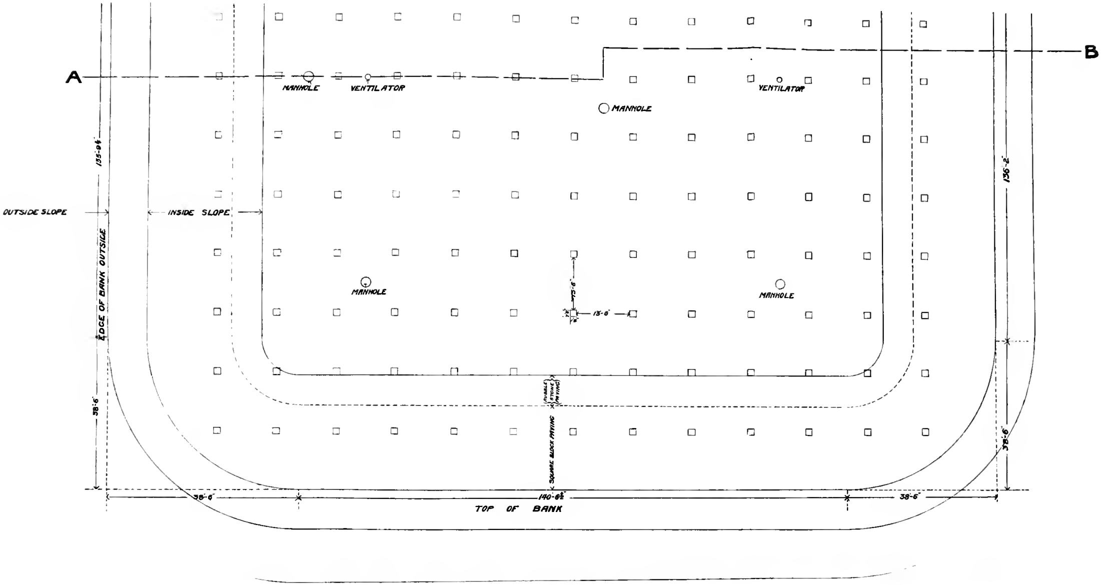
Referring to the reservoir bottom, I find that only 4-inch concrete finished with rendering is stated to have been used. This thickness appears to me very slight indeed, and I do not know of any reservoirs in this country where a bottom is made so thin as here mentioned.

In the description of the Franklin reservoir, it is stated that the wall is built of boulder concrete I am very much interested in this method of construction, but should have supposed that for ordinary reservoir walls such a method would have considerably weakened the wall itself, a reservoir wall being very different indeed from that of a large dam. Further on it is stated that the wall was pointed with cement mortar, and received several brush coats of neat cement and water. I fail to see the object of several brush coats, and shall be glad of information thereon.

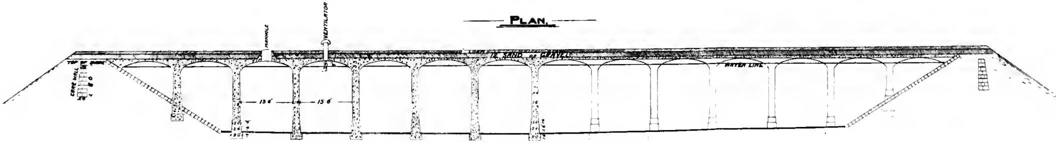
The author states that the introduction of reinforced concrete is a marked feature in recent reservoir and filter construction. I entirely agree with him and believe that there is a great future for reinforced concrete in constructional works of all descriptions. I would point out that the thicknesses of walls, roofs, etc., appear to me to be hardly sufficient to insure perfect safety, and generally speaking, they are slighter than would be considered necessary in similar works in England.

In reply to the communication of Mr. Thomas R. Smith on the paper, the author does not understand what induced the American engineers to adopt so largely the groined arch, certainly it was not economy in the cost of construction. As to the use of extra wet concrete by American engineers, he points out that in all reservoir work in America the concrete is put in extra wet, but he agrees with Mr. Smith that the English practice of making the concrete only moderately wet, and well ramming it is preferable. He does not think that the method adopted in the construction of the Franklin reservoir wall, viz. of introducing 40 per cent. of boulders in the concrete wall was one that English engineers would look with favour upon, although a slight saving in cost may have been effected. He considers that reinforced concrete has been very advantageously used in the construction of the Rockford reservoir.

In reply to the communication of Mr. C. H. Priestley, Mr. Matthews states that he is unable to give any further particulars with regard to the core wall which was built in connection with the re-construction of the Natick reservoir. It was entirely contrary, as Mr. Priestley states, to our English practice to place a core wall in the same position as that shown on Plate I. He observes that it is now the generally recognised practice in America to store ground water in covered reservoirs, no doubt one of the reasons why this is done, is that given by Mr. Priestley, viz. that great variations of temperature with extreme frosts occur in that country. Mr. Matthews agrees with Mr. Priestley that open service reservoirs, speaking generally, are preferable to covered ones, that is, of course, if they can be constructed in positions where they would be entirely free from contamination, from smoke, coal dust, or anything else that is objectionable. Unfortunately these favourable conditions are not always met with, and where a service reservoir has to be covered in, it is his opinion that reinforced concrete is the best material to be used. He is unable to say what benefit is derived by giving the walls of one of the reservoirs described in the paper several brush coats of mortar, which is contrary to English practice. He agrees with Mr. Priestley that the walls of some of the reservoirs described in the paper are of very much lighter construction than would be adopted in this country.


A
B
MANHOLE
VENTILATOR
MANHOLE
VENTILATOR
OUTSIDE SLOPE
INSIDE SLOPE
EDGE OF BANK OUTSIDE
135-9½
136-2
MANHOLE
MANHOLE
13-6
13-6
RUBBLE STONE PAVING
SQUARE BLOCK PAVING
38-6
38-6
38-6
38-6
140-6½
TOP OF BANK

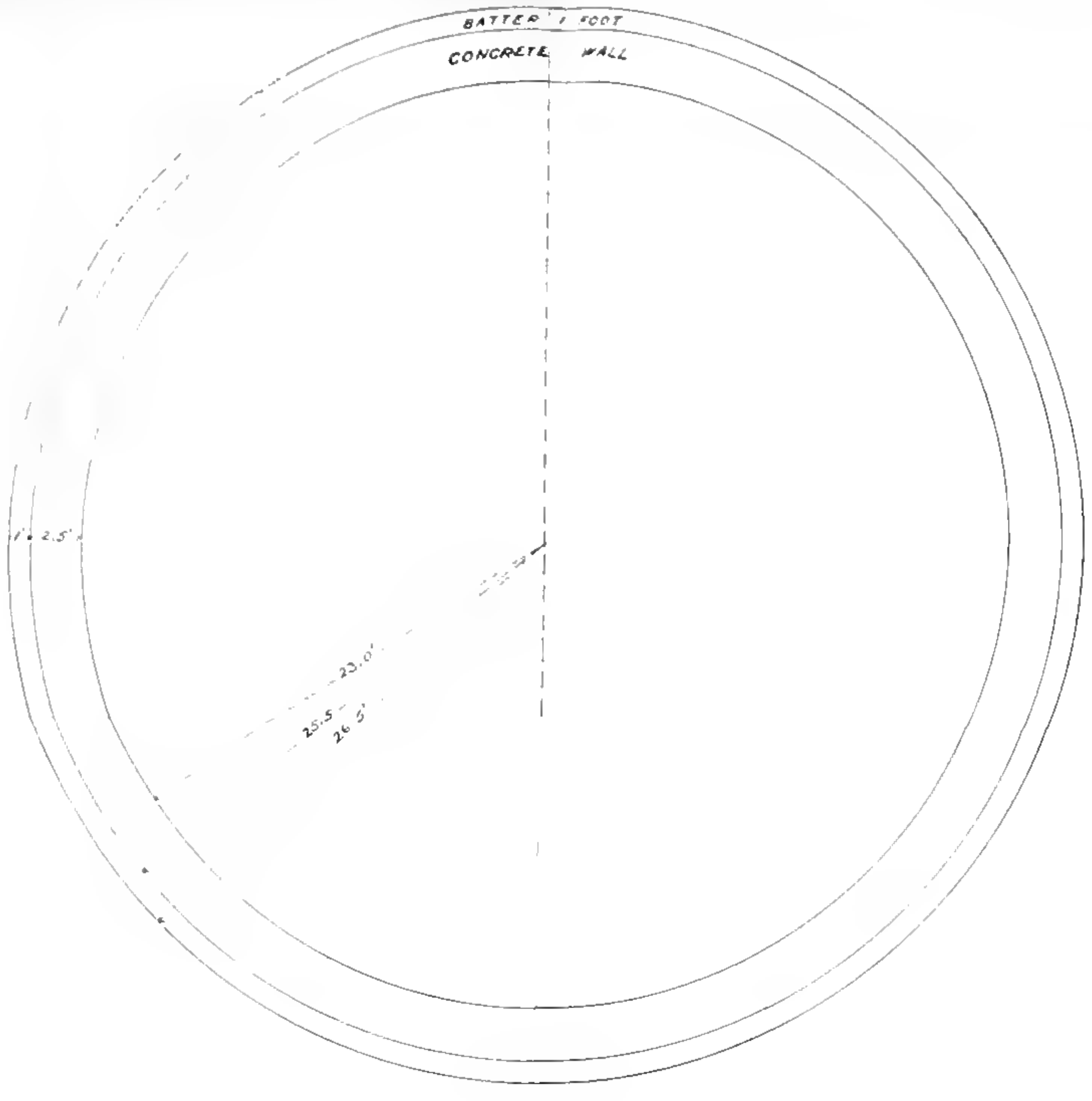
PLAN.


MANHOLE
VENTILATOR
12 SAND OR GRAVEL
WATER LINE
TOP OF BANK
CORE WALL
13 6
13 6

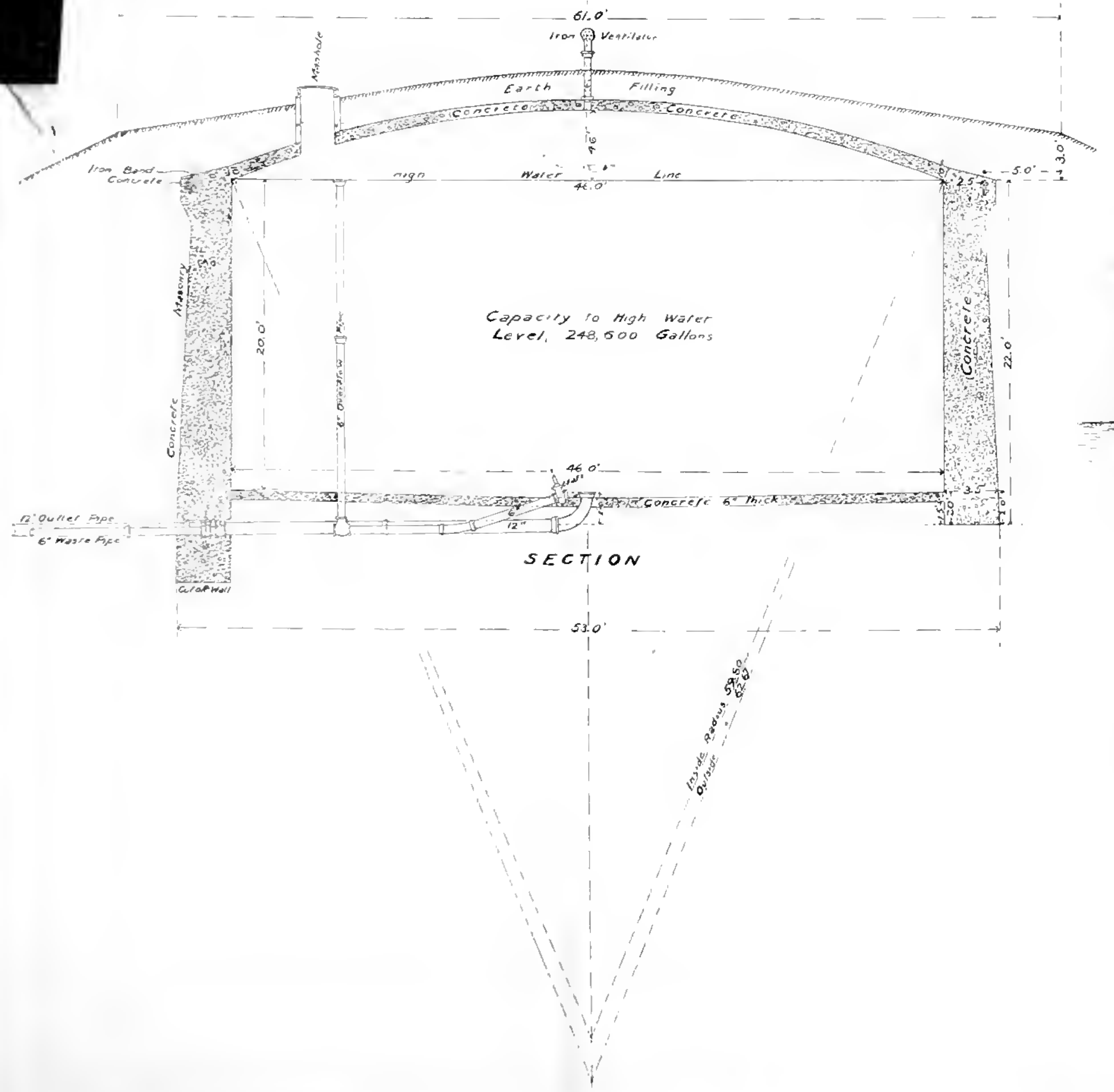
SECTION ON LINE A.B.

SCALE IN FEET

FIG. 1.


BATTER 1 FOOT
CONCRETE WALL
1 : 2.5
23.0'
25.5'
26.5'

PLAN


61.0'
Iron Ventilator
Manhole
Earth Filling
Concrete
Concrete
4'6"
Iron Band
Concrete
High Water Line
46.0'
5.0'
3.0'
2.5
Masonry
20.0'
6" Overflow
Capacity to High Water Level, 248,500 Gallons
Concrete
Concrete
22.0'
46.0'
Concrete 6" thick
12" Outlet Pipe
6" Waste Pipe
12"
3.5
2.0
Cut off Wall
53.0'
Radius 59.50
62.67

SECTION

FIG. 2.

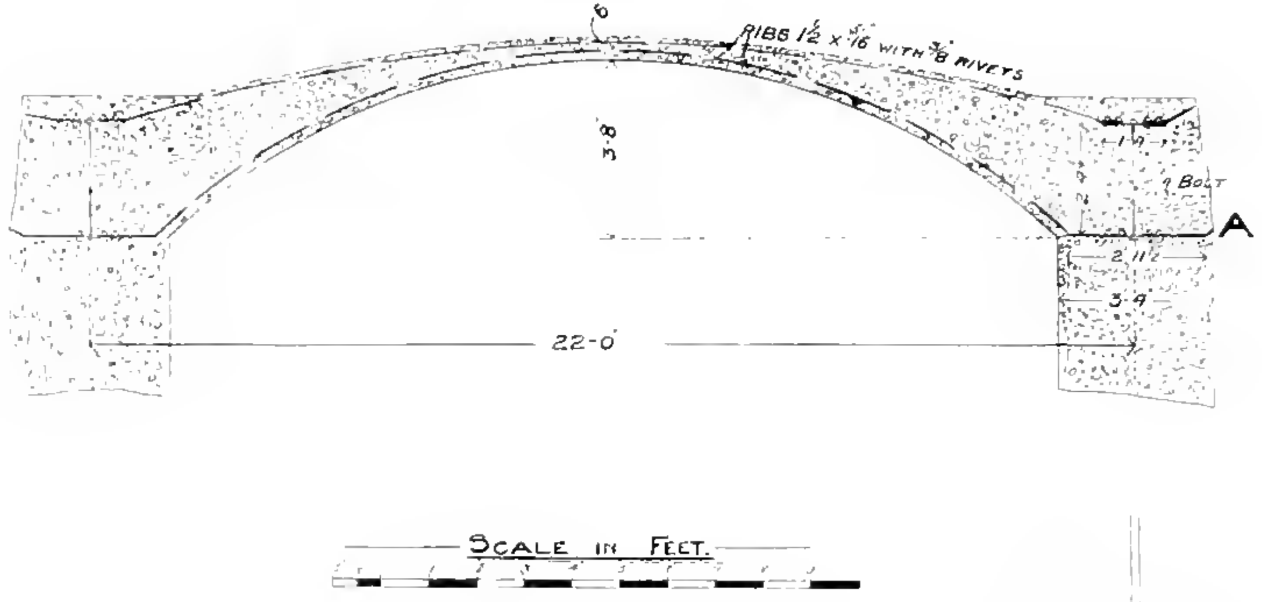
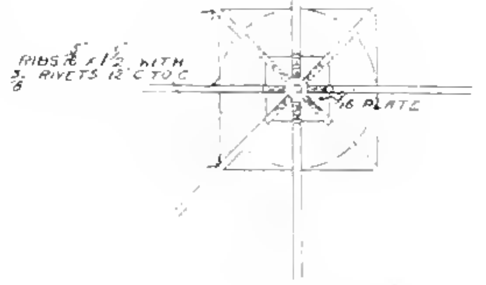

6"
RIBS 1½ x 5/16 WITH 3/8 RIVETS
3'8"
1'9"
Bolt
A
2'11½
3'9
22'-0"
SCALE IN FEET.

FIG. 3.


RIBS 5/16 x 1½ WITH 3/8 RIVETS 12" C TO C
5/16 PLATE

PLAN AT A.

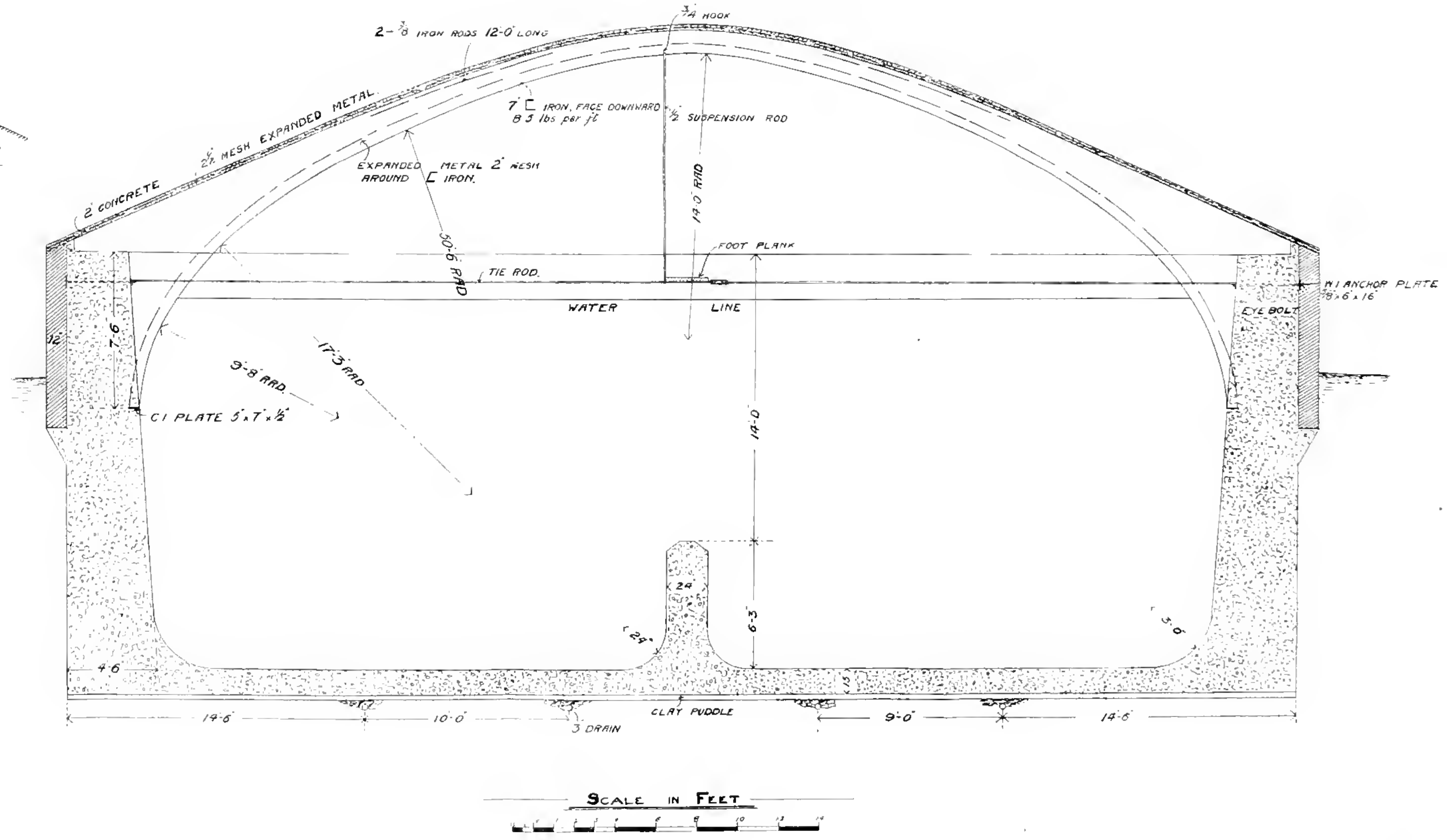
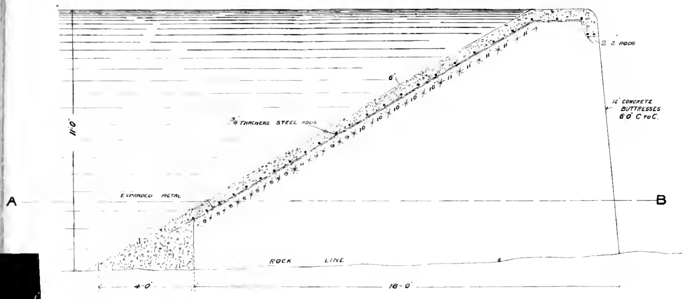
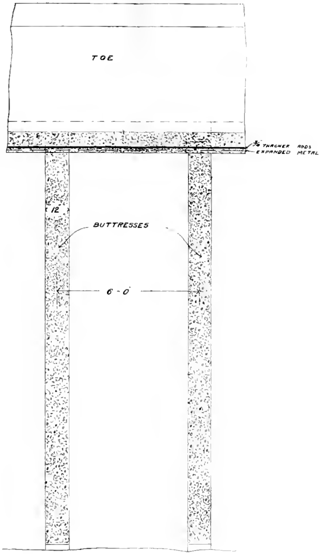

2 - 3/8 IRON RODS 12'-0" LONG
3/4 HOOK
2½" MESH EXPANDED METAL
7" ⊏ IRON, FACE DOWNWARD 9.5 lbs per ft
½ SUSPENSION ROD
2" CONCRETE
EXPANDED METAL 2" MESH AROUND ⊏ IRON.
14'0" RAD
50'6" RAD
FOOT PLANK
TIE ROD.
W.I. ANCHOR PLATE 18 x 6 x ½
EYE BOLT
WATER LINE
12"
7'6"
9'8" RAD.
17'3" RAD
C.I. PLATE 5" x 7" x ½
14'0"
24"
24"
6'3"
5'6"
4'6"
1'3
19'6"
10'0"
9'0"
14'6"
CLAY PUDDLE
3" DRAIN
SCALE IN FEET

FIG. 4.


11'0"
6"
2 2 RODS
¾ THACHERS STEEL RODS
12" CONCRETE BUTTRESSES 6'0" C TO C.
A
EXPANDED METAL
B
ROCK LINE
4'0"
18'0"

Scale in Feet.

Fig 5


TOE
¾ THACHER RODS
EXPANDED METAL
12
BUTTRESSES
6'0"

PLAN ON LINE A.B.

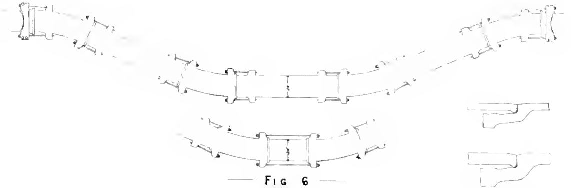


Fig 6

Fig 8

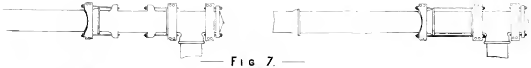


Fig 7.

June 3rd, 1907.

JOSEPH WILLIAM WILSON, VICE-PRESIDENT,
IN THE CHAIR.

WORKING EXPERIENCES WITH LARGE GAS ENGINES.*

BY CECIL A. ST. GEORGE MOORE, B.A. Camb.

INTRODUCTION.

THE production of power by the use of large gas engines has developed at a remarkable rate during the last few years, and much has been written on the subject. Most of the literature is, however, written from the manufacturers' point of view, and generally by the manufacturers themselves, and it deals almost exclusively with points of design. We have very little information about the actual behaviour of these engines in everyday working, the only paper treating this side of the subject which the author has seen being one which appeared in "Stahl und Eisen" about eighteen months ago, and which has never been published in English.

The present paper has been written to show some of the defects which have presented themselves in actual work, and by what means and to what extent they have been overcome. It is, however, only fair to manufacturers to state at the outset that the author's experience has been with engines built eighteen months ago and longer, and that many of the troubles herein mentioned would not occur in engines built at the present time, owing to improvements in design.

The conservatism which seems natural to British engineers has done much to keep back the development of large gas engines in this country. Consulting engineers, who have, in most cases, had no experience of these engines, are naturally reluctant to specify machinery of the reliability of which they have no personal, and probably very little second-hand, knowledge. Consequently, in many cases steam plant is put down where gas engines would have served the purpose equally well, and would have produced the power for half the cost. Conservatism also shows itself in the designs of large engines which have originated in this country, as nearly all English makers are working in the direction of developing for large sizes the same type of engine which has been found to work satisfactorily in small units. On the Continent, however, where the manufacture of small gas engines has not been such a large industry as with us, new lines have been followed in designing larger sizes, in most cases following the general form of the horizontal steam engine, alterations from this form having been made where found necessary.

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* A Society's Premium was awarded to the author for this paper.

TYPES OF ENGINES.

No one type of engine has yet proved itself superior to all others. The engines built on the Continent can be classed under three main heads, viz.: (1) The double-acting four-cycle type, generally made in large sizes with tandem cylinders; (2) the Oechelhaüser type; and (3) the Körting type. All three types are now made in this country under licence; engines of the first type, designed in England, are also made by one or two firms. Several other English firms have, however, struck out lines of their own, generally retaining the familiar open cylinder and trunk piston, the cylinders usually being kept as small as possible, and the power being increased by adding to their number.

The vertical type is almost peculiar to this country and it has been adopted for engines as large as 700 B.H.P. or more by several firms, notably the Campbell Gas Engine Co., the British Westinghouse Co., and Messrs. A. Rodger and Co. Two complications which many firms seem very anxious to avoid are water-cooled moving parts and piston rod packing. The 750 B.H.P. engine built by the British Westinghouse Co. has no fewer than six open cylinders with trunk pistons, in three tandem sets, no water cooling being used for either pistons or exhaust valves. The Campbell engine of about the same size has four vertical open cylinders side by side, while the National Co. have four horizontal cylinders side by side. The Premier Co. have developed a type of engine with four horizontal single-acting cylinders in two tandem sets, water-cooling being used for the pistons and exhaust valves. The engine is made in sizes up to about 1200 B.H.P. Messrs. Crossley Bros. and Kynoch, Ltd., are building double-acting tandem engines of the continental type of their own design.

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SCAVENGING.

The value of positive scavenging in engines of the four-cycle type is still regarded as an open question. In most of the large continental engines no scavenging is attempted, it being presumably thought that the results obtained are not worth the extra complication. In this country all the Premier engines are fitted with a positive scavenging device, and it is claimed that, owing to the clearing out of all the burnt gases in the cylinder, there is no tendency to fire during the suction stroke, and that the charge of fresh air keeps the engine cooler, and hence there is less tendency to pre-ignition. Experiments made some years ago by Mr. F. Grover seemed to show that a mixture of air, coal gas, and exhaust gas gave better results than if the exhaust gas were replaced by more air. It also must be remembered that explosions during the suction stroke are, as a matter of fact, quite harmless, and in a non-scavenging engine they occur very seldom if everything is working properly. Theoretically it seems, however, that if the clearance space is full of pure air at the commencement of the suction stroke, a stronger mixture might be drawn in, and consequently an increase of power might be obtained with an engine of the scavenging type, as the air already in the cylinder would serve for the combustion of the extra gas drawn in.

GOVERNING.

The governing of gas engines of the four-cycle type has received very careful attention from continental engineers. The hit-and-miss method, which has been the universal practice for small engines, is satisfactory in sizes up to 200 H.P. for driving direct current dynamos. If the engine has several cylinders, and a separate governor for each, there is no reason why this method should not be used for still larger sizes, provided that each cylinder does not develop more than about 100 H.P.

For driving alternators and other work where a steady turning moment is necessary, some other method must be employed. The plan most usually adopted is to provide a varying cut-off for the gas on the suction stroke, the gas and air valves opening together at the commencement of the stroke, the gas valve closing at a variable point determined by the governor, and the air valve remaining open until the end of the stroke. The provision of a separate air valve is not essential, but this is used in the Cockerill engine. This method gives a weaker mixture as the load is reduced, the compression pressure remaining constant. At very light loads misfiring is likely to result, owing to the extremely weak mixture, hence there is usually a supplementary arrangement for cutting out explosions entirely when the speed exceeds a certain value.

Another method of governing is to cut off the gas and air together at a varying point on the suction stroke, thus giving a mixture of constant proportions but variable quantity. At light loads when the cut-off is early the pressure in the cylinder at the end of the suction stroke falls very much below atmospheric, and in order to prevent the valves being opened by the atmospheric pressure outside, a positive mechanism must be provided for keeping them closed. In the Cockerill engine this takes the form of a double roller for each cam, the rollers being placed on opposite sides of the cam so as to act positively on the valves in both directions. The Cockerill engine is supplied with either method of governing, at the option of the purchaser.

The by-pass governor valve as commonly used on the Körting engine is not satisfactory with producer gas, as the deposited tar frequently causes it to stick. Governing by a variable cut-off on the suction stroke has been tried with this type of engine, but has not been found satisfactory owing to the heavy suction produced in the gas pump. A simple and fairly efficient form of governor for this engine is an ordinary butterfly valve in the gas pipe, as employed in the older types of steam engines. If set very carefully this will prevent serious racing when the load is thrown off, but will not give a very small speed variation in ordinary working. For direct current work, however, this is not essential.

Two *v.* Four-Cycle Engines.

It is not necessary to describe here the action of the Körting and Oechelhaüser engines, as full descriptions have appeared in many engineering journals; all the latest details of continental gas engine practice will be found in the long series of articles that have lately appeared in "Power."

The principal advantages claimed by the makers of the Körting engine for that type are regular turning moment with one cylinder; reduced floor space, and the absence of water-cooled exhaust valves. It is evident that a single cylinder engine of this type will give approximately the same power as a double-cylinder engine of the same bore and stroke working on the four-stroke cycle. But opposed to this there are several points to be considered. Owing to the great length of the piston in the Körting engine, and also to the fact that it is a slow-speed engine with a very long stroke, the total length of the engine is not far short of that of a four-cycle engine of the same power, whereas, owing to the space taken up by the charging pumps, the breadth of the Körting engine is very much the greater. The Körting and Oechelhaüser engines possess one great and indisputable advantage over the Otto cycle type, namely, the absence of water-cooled exhaust valves.

The thermal and mechanical efficiencies of the Körting type of engine are both comparatively low, for the following reasons: The charge has to be pumped into the working cylinder in a very short time, and a good part of it enters while the exhaust ports are uncovered. Although air is pumped in first, a certain amount of gas always finds its way through into the exhaust pipe when the engine is working at full load, and hence the delivery of gas begins early; the quantity lost amounts to from 15 to 20 per cent. of the whole charge. This the author has seen verified by systematic analyses of the exhaust gas, taken from two different engines under various conditions. In some tests of an engine of this type belonging to the Société Anonyme de Grivegnée, made a year ago, there was an unexplained loss of 30 per cent. in the heat balance, and those in charge of the tests concluded that this was due either to incomplete combustion or to direct expulsion of gas into the exhaust. No analyses of the exhaust gases were made in connection with these tests.

With regard to mechanical efficiency, since the power required to work the charging pumps varies from 12 to 15 per cent. of that indicated in the working cylinder, the said efficiency must be much less than that of the four-cycle type. The combined efficiency of a Körting engine and dynamo is not usually more than from 70 per cent. to 75 per cent.

The Oechelhaüser type of two-cycle engine has several very excellent features which are possessed by no other engine. Among them may be enumerated the following: (1) The opposite cranks make it possible to balance the engine very perfectly; (2) There are no valves of any kind in the working cylinders; (3) The working cylinder is open at both ends, making satisfactory lubrication an easy matter, and simplifying the operation of inspecting the cylinder and pistons; (4) There are no complicated cylinder covers which are liable to give trouble by cracking; (5) The two pistons moving in opposite directions give a very rapid expansion and compression.

PISTON OF THE KÖRTING ENGINE.

There has been much to learn with regard to the design of the piston for engines of the Körting type. Owing to its great length and weight it is difficult to make it a satisfactory and reliable job. If the engine is not fitted with a tail rod the piston is generally a plain cylindrical casting. If the rod is fixed to the piston by means of a flanged end the joint must be made with a copper ring, as no soft jointing material will keep tight for more than a day or two under the stresses caused by the explosion, since the joint is alternately in tension and compression, as the explosion occurs at either end of the cylinder. A section of this form of joint is shown in Fig. 1. If this form of joint is used, the internal flange of the piston will certainly sooner or later crack radially through two or three of the stud holes, as shown in Fig. 2. The original cause of these cracks is apparently the stress due to cooling, combined with the rather severe conditions of work. These cracks must get very bad before there is any danger of the piston breaking, and so long as they do not extend beyond the studs the engine may quite safely work. If ribs are cast inside the piston at the corners, these will all crack through in a very short time, the cause being apparently cooling strains in this case also.

Another method of fixing the rod is by means of a large nut outside the piston, a collar on the end of the rod bearing against the latter inside, the rod being inserted through a detachable cover at the back end of the piston. This is shown in Fig. 3. The objection to this method is that after running a short time the nut usually gets stuck so fast that it is quite impossible to get it off, so that when it is required to turn up the rod it is necessary to mount it and the piston together in the lathe. The author has seen two pistons break off round this nut, as shown in Fig. 3. In one case this happened while the engine was running, the result being that both the cylinder and the front cover were smashed. In the second case, by pure accident, the engine happened to be stopped just in time, and when the cylinder was opened the piston was found quite loose. Messrs. Mather and Platt have lately designed a piston which should be without most of the failings enumerated. It is made in three pieces; the two ends are steel forgings and are bolted to a plain cast-iron cylindrical barrel, the latter being made of larger diameter than the ends to avoid any rubbing contact between the steel and the cast-iron cylinder.

With the heavy pistons used on the Körting engine, it is a very good thing to have the bottom shod with white metal, which takes up the wear, and which can be renewed from time to time; otherwise if the whole weight of the piston rests on the bottom of the cylinder, the wear of the latter will be very great. The white metal should stand out about one millimetre from the body of the piston. Any attempt to make the piston barrel other than cylindrical, to facilitate renewal of the white metal, or for any other reason, will always have one result—the piston will crack. If the engine is fitted with a tail rod, the rod should either be continuous right through the piston, or the two rods should be bolted rigidly together. In no case should the cast-iron piston block be used as a connecting link between the two rods.

CRACKING OF CYLINDERS.

The complicated form of the cylinder head of the Körting engine renders it very liable to give trouble by cracking. The usual pattern cast in one piece does not as a rule last more than a year, if working fairly continuously, although, of course, there are exceptional cases when one may last much longer. The outside walls, fortunately, generally crack first, owing to the expansion of the inner wall by heat. They usually give way first along the root of the flange, and also at the corners of the rectangular holes giving access to the jacket space. These cracks begin and spread very gradually, and there is practically no danger of a sudden failure, so that the engine can be run for a long time after these cracks have shown themselves, provided, of course, that the internal walls of the head are quite sound. The author has seen an engine running with a crack 2 feet long in the outer wall at the root of the flange. If a crack occurs in the internal walls of the cylinder or head, the engine must, of course, be stopped immediately. Such a crack can always be detected while the engine is running by watching the jacket water discharge. The gas blown into the jacket through the crack will cause periodic stoppages of the flow of water in order to get out, provided that there is no opening at the top of the jacket. If the cylinder is cast on a chill a great number of minute circumferential cracks from 6 to 8 inches long generally appear inside after a short time, but these have been found to be quite harmless, as they do not extend to any appreciable depth in the metal, and after a time they do not seem to spread.

WEAR OF CYLINDERS.

The following figures regarding the wear in the cylinder of a Körting engine after eight months' work are interesting.

Diameters of cylinder, in inches:—

	July 5th, 1905.	March 16th, 1906.
Front end vertical	29·925	29·990
„ „ **horizontal**	29·911	29·956
Centre of ports vertical	29·995	30·025
„ „ **horizontal**	29·975	30·000
Back end vertical	29·911	29·975
„ „ **horizontal**	29·890	29·963

These figures show that the greatest wear takes place in the middle of the cylinder at the exhaust ports. The reasons for this are evidently (1) part of the cylinder is crossed by both sets of rings, and (2) the reduced wearing surface at the exhaust ports. The engine in question had its piston shod with white metal, but no attempt was made to keep the weight of the piston off the cylinder by cambering the rods.

Cambering of Piston Rods.

It is now the fairly universal practice to fit large double-acting engines with tail rods, but it is still an open question whether it is expedient to camber the rods, so that the whole weight of the piston is taken by the guides. The crudest method of doing this is to measure the sag due to the weight of the piston, and mount the rods at such an angle that the piston would be correctly in line when supported only at the ends of the rods. It is evident that the rods will not now be straight, but will be bent in a curve the lowest point of which is midway between the piston and the point of support. This is unsatisfactory, as no packing will last long under this up-and-down motion of the rods. If the rods are to be straight when supporting the piston, they must be made primarily in the form of a curve. Of course, to do this exactly is impossible, but an attempt is made to approximate to it in continental practice by turning up the rod in short lengths at a time, each length being turned on different centres, thus producing part of a very flat polygon. The only absolutely correct method is to turn up the rod by means of a revolving tool, the rod remaining stationary, and supporting the piston meanwhile. This would be a difficult and expensive method in practice, and it would not be easy to turn up the rod again in an ordinary repair shop. If no cambering of the rods is attempted, it is doubtful whether a tail rod is of any great advantage, at any rate for engines of less than 500 H.P., and it is the author's experience that an engine of the Körting type will run quite well without one, provided that the piston is properly shod with white metal. The addition of a second stuffing-box counteracts to a great extent the advantages of a tail rod.

Packing.

The production of a good metallic packing forms one of the most difficult problems in gas engine work. The essentials of a satisfactory packing are: (1) It must not wear the rod unduly; (2) The rings must not break or become corroded by the action of the gas; (3) It must be readily accessible for cleaning;

(4) It must accommodate itself to any motion of the rod at right angles to its axis, and also to small differences in diameter between one part of the rod and another.

Considering the question of the material of which the packing rings are to be made, we have the choice of three metals, namely, cast-iron, some form of brass or gunmetal, and white metal. Cast-iron stands heat well, but is inclined to cause undue wear of the rod. Any metal containing copper is very rapidly corroded away, if the products of combustion (which generally contain a small amount of SO_2) can get at it. White metal will not stand any heat, wears away rapidly, and is easily broken. Cast-iron has been found by experience to be on the whole the most satisfactory material, though it is very important that it should be very soft, and that the rings should be given very little spring on the rod, otherwise excessive wear will result. With an 8-inch rod it is quite enough if the rings are bored out $\frac{1}{64}$ inch less than the diameter of the rod. In this case after running about a month one or two of the rings nearest the cylinder will have become just slack on the rod, but these can easily be renewed.

The most satisfactory form of ring is rectangular in section, and should not be too narrow. This should be surrounded by an L shaped solid ring which is made an accurate fit inside the packing-box. The box should contain eight or ten of these double rings, which should be held up to their work by spiral springs acting parallel with the rod. White metal V shaped rings may be used with advantage at the outside end of the packing, well away from the hot end. They should preferably be put in a separate box fitting inside the main packing-box. The rings in this part of the packing which do not touch the rod should be of brass or gunmetal. The packing-box should be made in two halves for the sake of accessibility, and should be water-jacketed. If this is not done, things may be all right for a time; but if there is any blow, the box will soon become nearly red-hot, with the result that the packing will deteriorate very quickly. A sketch (not to scale) of the packing described is shown in Fig 4. It is the only packing which the author has found even moderately satisfactory after three years of experimenting on two engines by four different firms of packing manufacturers, during which time something like ten different types of packing were tried.

Stratification of Gaseous Mixtures.

Much has been written regarding the real or supposed stratification of the charge in the cylinders of large gas engines. The whole theory of the Körting cycle depends on the assumption that this stratification takes place, and evidently to a certain extent it must be so, as the diffusion of gases cannot take place instantaneously. However, it appears that even during the short time required for the admission of the charge in the Körting engine, a considerable amount of diffusion takes place, as is shown by the loss of part of the charge through the exhaust ports previously referred to. In view of this, it scarcely seems likely that the charge will remain in any considerably stratified condition throughout the compression stroke up to the time of ignition. It is claimed by many gas engine builders, however, that this is the case, and that when running at low loads there will be a fairly strong mixture in the vicinity of the ignition plugs, although the average charge in the cylinder may be very weak.

Whatever the actual state of things in this matter may be, some very curious and apparently puzzling facts regarding the effect of the position of the ignition plugs have been brought to light. The engines on which these experiments were made have two low-tension igniters at each end of the cylinder, one right at the end in a pocket below the inlet valve, and the other at the side, and nearer the piston. It was found that if the end plug was disconnected while the engine was running, there was no visible effect, but if the side plug was out of action there was a falling off in the power produced at that end of the cylinder of about 15 per cent. The difference was not always so great as this, but there was always quite a perceptible drop in the power when either of the side plugs was not working. Ignition from the side gives a sharper explosion and a more rapid burning of the charge, and consequently a lower expansion line. Figs. 5 and 6 are reproduced from indicator diagrams taken by the author, and show the effect very well. At the time the engine was working on a steady load at about two-thirds full power. At higher loads the effect was not so marked.

Timing of Ignition.

The correct timing of the ignition is a very important factor in the running of a gas engine, if economical working is to be attained. An arrangement for altering the timing while the engine is running should always be provided, and this should be calibrated with the help of indicator diagrams. Many engineers are inclined to run their engines with the ignition too late, with the idea that the lower maximum pressure and slower combustion is conducive to smoother running and reduced wear and tear. Fig. 8 shows an indicator diagram with the ignition too early. Fig. 7 shows another diagram taken at the same time after it had been retarded a little, the timing in this case being correct. The timing should be so set that the explosion line is vertical, not leaning back. Some engineers argue that with later ignition a higher expansion line is obtained, and hence the power is not reduced, but as a matter of fact repeated experiments have shown that the maximum power is obtained with a vertical explosion line, the extra pressure thus gained during the early part of the stroke more than making up for the lower expansion curve. At light loads when working with a weak mixture it will be found necessary in order to get the best results to advance the ignition more than at full load, to compensate for the slower combustion of the charge.

Pre-ignition.

One of the most persistent troubles which users of large gas engines have to contend with is the liability to pre-ignition. Pre-ignitions are not in themselves dangerous provided they keep within limits. It is the author's experience that with large engines with cylinders upwards of 2 feet diameter, pre-ignitions are never entirely absent, at any rate when running on producer gas, but if everything is all right they should not occur more frequently than once every two or three hours. Under unfavourable conditions, however, they may occur every two or three revolutions, and in extreme cases may occur every revolution, when of course the engine will pull itself up if the load is not taken off immediately. Pre-ignitions may occur at almost any point of the compression stroke, as shown by Figs. 9 to 12.

In the Körting engine the fresh gas is pumped into the cylinder before the hot exhaust from the previous explosion has been entirely expelled, and although there should be a layer of air between the exhaust and the fresh charge, as a matter of fact ignition of the charge occasionally takes place at this point, presumably by its contact with the hot exhaust gas. At this time the exhaust ports are uncovered, and the inlet valve is also open, so that the cylinder is in communication both with the exhaust pipe and with the gas and air pumps. Occasional pre-ignitions of this type are perfectly harmless, although to the uninitiated observer they sound very terrible. The outward effect is a bang in the exhaust pipe, followed by a loud rap from somewhere in the neighbourhood of the inlet valve. Fig. 12 shows a pre-ignition of this kind. It will be seen that since the explosion starts at atmospheric pressure and the cylinder is open to exhaust no pressure of any consequence is reached, the only result being noise and the loss of a working stroke. Fig. 13 shows another specimen of the same thing, the diagram in this case having been taken with a light spring. In this figure A is the expansion line; B, expansion after pre-ignition; C, pre-ignition; D, ordinary compression line. The effect of these explosions in the gas and air pumps is shown in Figs. 14 and 15, which are indicator diagrams taken from the gas and air pumps respectively. The sudden rise of pressure is due to the explosion taking place in the cylinder while the inlet valve is open and causing a blow back into the pumps. When an engine is running light, especially when just started after having been at rest for some time, this firing back may occur almost continuously, but, in most cases, when the load is put on it will decrease, and by the time half to two-thirds load is reached will probably cease altogether. The only explanation of this phenomenon that occurs to the author is that, with the weak explosive mixture in the cylinder at light loads, the burning is so slow that combustion is not complete at the time of exhaust, and the lingering flame tends to ignite the fresh charge.

On one occasion an engine when running at about $\frac{3}{4}$ load was firing back very frequently in the manner described, and it was found on examination that the wire to the side ignition plug had become disconnected. When this wire was connected up there was an appreciable rise in the power and the firing back ceased. This is very difficult to explain satisfactorily, but it seems that the slow burning of the gas, which apparently takes place when the end plug only is in action (see Fig. 6) caused ignition of the entering charge at the end of the stroke. It is to be noted that when the side wire was disconnected the engine was not missing fire.

Pre-ignitions of the ordinary type, as shown in Fig. 9, are evidently caused by overheating of something inside the cylinder. If the piston rings are broken, and hot gas is blowing past the piston, the latter becomes overheated at the edge, causing pre-ignition. The effect of this is very often seen when the piston is taken out after the engine has been running with broken rings. Pre-ignitions may also be caused by firing past the rings from one side of the piston to the other if the former are in bad order. This is most likely to occur in the two-stroke engine, as in this case the compression takes place at one side of the piston while combustion is going on at the other, and the compressed charge is likely to lead past the rings and become ignited at the other side of the piston, the flame then travelling back and causing a premature explosion of the charge.

In the Körting engine it often happens that broken pieces of the rings drop into the exhaust ports and stick there, so that the piston on its return shears off a piece of ring which then gets into the explosion space. This piece of ring may get red-hot and cause pre-ignitions.

Utilisation of Waste Heat.

No installation of large gas engines is complete without some means for utilising the heat carried away by the exhaust. The most satisfactory way of doing this is to pass the exhaust through a boiler. The steam generated may be used for a variety of purposes, such as supplying the producers, heating, running a small steam engine, etc. The exhaust from any engine will generate enough steam for the production of all the gas the engine requires, so that if the gas is only used for engines, no separate boilers are required for the producers. A horizontal tubular boiler is the most satisfactory type to use, and this should be placed as close to the engine as possible. The exhaust pipe leading from the engine to the boiler should be cast with a jacket, and used either as a feed-water heater or as a superheater. The most efficient method is to use the exhaust after it leaves the boiler as a feed-water heater, and to superheat the steam by passing it round the exhaust pipe leading to the boiler. Owing, however, to the great heat attained by the pipe nearest the engine, trouble may be experienced with steam joints, etc., so that in practice it is more reliable to keep the pipe nearest the engine water-jacketed. Great care should be taken to fix the boiler so as to avoid vibration as much as possible, otherwise trouble may arise from the tubes shaking loose.

Producer Gas.

The following remarks concern gas made in a pressure producer using bituminous coal, and must not be taken to apply to suction gas. The relative advantages of producer gas as compared with blast-furnace gas for use in large engines have been much discussed. The Mond type of producer is that which is most used for large plants, and the author's experience is that Mond gas is quite satisfactory for large engines, if reasonable care is taken in its use. The gas must be thoroughly cleaned, otherwise trouble is bound to ensue, owing to the valves of the engines sticking. Mond gas contains an enormous amount of tar, which is very difficult to get rid of. Some kind of washing arrangement and two sawdust scrubbers in series are absolutely necessary. For washing purposes an old Lancashire boiler set vertically is useful. This should be packed with ring tiles, and the gas should pass upwards through it, water meanwhile dripping downwards over the tiles, and being carried away by a drain through a water seal at the bottom. This process, besides extracting a certain amount of tar from the gas, also cools it very effectively.

At any temperature a certain amount of tar remains in a gaseous form, and the higher the temperature of the gas the more tar will remain in it in this state. Hence it is always advisable to cool the gas down as nearly to atmospheric temperature as possible. After passing through a tower, as described, and then through two sawdust scrubbers, the gas should be absolutely invisible, and should leave no stain on a piece of white paper, showing that it is free from tar in suspension. Even when the gas is in this condition, after a very short time the gas valve and mixing chamber of a four-stroke engine, or the gas piston valve of a Körting engine, will become thickly coated with tar, and a thorough cleaning of these will be necessary about once a fortnight. The cause of this deposit on the valves, etc., is apparently as follows: Although there is no tar in suspension in the gas, yet a certain amount is present in a gaseous form. During the suction stroke the pressure behind the gas regulating valve or stop valve may fall considerably below atmospheric pressure, especially if the engine is running on a light load with the gas supply much throttled. This fall of pressure is accompanied by a corresponding fall in temperature, hence some of the gasified tar condenses and is deposited in the neighbourhood of the valves. The author has suggested (although he has not been able to make any experiments in that connection) that after cooling the gas to atmospheric temperature it should be heated again before being taken to the engine. This heating would make up for the fall in temperarure during the suction stroke, and hence the deposition of tar would probably be avoided, and it would be carried over to the cylinder and there burnt. The exhaust might be used for heating the gas for this purpose.

In the case of the four-cycle engine, the effect of the tar depositing is usually to make the gas valve stick open. This valve, which is generally closed by a fairly light spring, sticks open much more readily than the inlet valve. This results in a series of explosions in the air pipe, which, although very noisy, are comparatively harmless. A good dose of tar oil will generally free the valve temporarily, if it is necessary to avoid stopping the engine.

It has been frequently debated whether a gas containing a comparatively large percentage of hydrogen is suitable for large engines. A point which is often overlooked is that the temperature of combustion of hydrogen is considerably lower than that of carbonic oxide, hence an engine running on Mond gas should, theoretically, keep cooler than one running on blast furnace gas. Against this we have to set the fact that hydrogen ignites at a lower temperature, and hence there is more liability to pre-ignition. The following is an average analysis of Mond gas :—

CO_2	16·4 per cent.	Calorific Value (higher scale) 159·4 B.T.U. per cubic ft.
O	0·2 „	
CO	11·4 „	
H	26·6 „	
CH_4	2·7 „	
N	42·7 „	

A small variation in the percentage of marsh gas causes a considerable difference in the calorific value, owing to the very high value of that constituent. The author has made very careful experiments to ascertain whether, within the limits of ordinary working of the Mond plant, there is an increased tendency to pre-ignition in large engines with increasing calorific value of the gas. The result arrived at was that between the values of 140 and 165 B.T.U. per cubic foot (on the higher scale) there was no perceptible difference in the running of the engines, except, of course, that the power increased as the value of the gas rose, if the engine was not controlled by the governor. During the experiments regular analyses of the gas were made from samples taken at the engine stop valve, notes being taken as to the running of the engine at the time. No relation could be found between the percentage of any one constituent of the gas and the behaviour of the engine.

If the load on a producer gas plant is suddenly largely reduced, gas of a very high value is given off for a short time, and this will cause violent pre-ignition, generally resulting in the engines pulling themselves up entirely. If, however, the driver is prepared, and, as soon as he sees the load begin to go up, keeps it steady by partly shutting off the gas at the stop valve, the temporary rise in value of the gas can be tided over without any trouble. On one occasion one large engine was running, and most of the remainder of the gas from the producers was used for firing two large water-tube boilers. After one of these boilers had been shut down for about ten minutes the load on the engine began to rise quickly, but was kept steady by a man at the stop valve. Meanwhile, the thermometer of the calorimeter in the engine-house was watched until it reached its highest point, and then the value of the gas was taken, and found to be 210 B.T.U. per cubic foot (on the higher scale). After twenty minutes it had fallen to its normal value again. During this time there was not a single pre-ignition.

This helps to explain the fact that large engines can be successfully run on coke-oven gas, provided that it is sufficiently diluted. An average sample of coke-oven gas gives the following analysis:—

CO_2	5·0	per cent.	Calorific Value (higher scale) 517 B.T.U. per cubic ft.
O	0·6	,,	
CO	5·6	,,	
H	41·8	,,	
CH_4	33·3	,,	
N	13·7	,,	

The author is informed that the gas of which the above is an analysis is being successfully used for driving engines of fairly large size at the Shelton Iron Works, Stoke.

DISCUSSION.

The CHAIRMAN moved a vote of thanks to the author, and in doing so, remarked that it was some years since the Society had a paper on the subject of gas-engines, the last having been read by Mr. S. Griffin in 1889. The subject of that paper was, "Modern Gas-Engine Practice," and the Bessemer Premium had been awarded for it. It was interesting to look at that paper in the light of what they had heard to-night, and of what engineers were accustomed to at the present time. Mr. Griffin, in his paper, said, " It is certain that, except within limited spheres, gas-engines and steam-engines could never be real competitors," and he went on to speak of the impossibility of our Atlantic liners, or swift railway trains, or colossal mills being propelled or actuated by motors using gas as fuel in their cylinders. This, in his opinion was beyond the limits of probability. In the present paper, Mr. C. St. George Moore had alluded to some large gas-engines, and probably all engineers knew that there were still greater schemes either actually being carried out, or being prepared for. The paper was interesting in that it had shown the matter from an up-to-date stand-point, and the author had been good enough to bring forward from his own experience some very interesting points of theory as well as of practice; and he asked the meeting to join in according him a hearty vote of thanks.

The motion was carried by acclamation.

Professor D. S. CAPPER said that the author had supplied a very real want, namely, a paper dealing with the practical troubles and difficulties in constructing and working large gas-engines, which the manufacturers had to face, and were facing in making gas-engines of large size. The author mentioned engines of the size of 1200 H.P., but did not speak of those larger engines which one occasionally reads of in print, but of which first-hand information was very difficult to obtain. The paper, therefore, was of very great interest, and he would try in the time at his disposal to touch upon a few of the many points for discussion which it opened up.

At the outset the author briefly compared the two- and the four-cycle engine, and said correctly that the two-cycle engine ought to be smaller than the four-cycle engine. At the same time he went on to show that the auxiliary pumps and other gearing did not, in practice, result in such a reduction of space occupied. In the speaker's view this pointed to almost certain improvements in the future, and, although size was a very important point, it led him to think of the comparison between a gas-engine and a steam engine on somewhat broader lines. He felt that if the gas-engine was, as many believed, destined to replace the steam-engine altogether (especially if a turbine gas-engine were ever produced) it was probable that advance in the future would be made by striking out even on bolder lines than had been as yet attempted. At the present time he thought it would be admitted that the gas-engine was not comparable, for all sorts and conditions of working, with the steam-engine; gas-engines, for example, could not be constructed as large as steam-engines, they could not be compressed into the same space (unless the boiler and gas-producer were included in the comparison) they could not be run with the same variation of speed and there were other points in which they were not at present on an equal footing.

On a small scale a good many of these points of difference had been removed, but on a large scale, for general use, he thought that his statement was correct. If the gas-engine is to replace the steam-engine, it must be able to compete with it in all spheres of work. He would return to this point later.

Referring to a few of the details which struck him as specially interesting in the paper, the author had dwelt chiefly perhaps with the Körting engine. That engine was very interesting as being a revival in a modified form of the earlier Clerk engine. He need not refer to the points that the author had described, which differentiated the Körting engine from most other gas engines; he would mention only one point, namely, the absence of an exhaust-valve, to which the author had referred. This, of course, enabled the engine to be run on the two-cycle without the consequent troubles from overheating of the exhaust-valves. The author had referred to the very interesting fact that the result of this arrangement was, in the engine which the author had experimented with, a very appreciable percentage of the gas charge escaped into the exhaust before the piston returned and closed the ports. The speaker could not help wondering whether this leakage was entirely due to the absence of exhaust valves. Was it not possible that some of the gas escaped past the piston when at high pressure? He was not aware of any experimental investigations into this very interesting and important point.

Another point which the author had touched upon was the stratification of the charge. Stratification had been very widely accepted on the authority of some of the soundest experimenters and pioneers in gas-engine work. The author pointed out that stratification appeared, from the evidence which had come to his notice, not to be so nearly perfect as had been supposed. Was it not possible that leakage past the piston might occur sufficiently to upset stratification and to produce longitudinal waves of gas, chiefly in the outer cylindrical ring of the charge, which would upset the transverse layers of gas and air which had been presumed to exist? The fact that stratification was not found so nearly perfect by the author as had been supposed did not therefore necessarily upset the stratification theory, but it might be another fact connected with the leakage of gas into the exhaust, to which the author had referred.

With regard to the use of white metal for coating the piston, the speaker would much like to know the constitution of the white metal used. If ordinary white metal with a low fusing point were used, it certainly seemed to point to a nearly perfect system of water jacketing for the piston and other heated parts, much more nearly perfect than the speaker had thought was possible. One knew very well that the cylinder walls were not of the temperature of the gas, or anywhere near it, and one also knew, of course, that the water-jacketed piston was not at anything like the temperature of the gas, but that a projecting mass of white metal, without itself being water cooled, could stand without destruction was remarkable. It was a fact probably not new to gas-engine manufacturers, but it was interesting to him, and he had no doubt to many others of the audience.

The author had referred to the wear of large horizontal cylinders, and there was no doubt that his statements in this respect were correct, but he should very much like to know whether in the figures given on page 121, experiments had been made to see how far what was apparently wear might have been due to distortion of the cylinders. With large castings internal stresses in the metal were of course present, and with the very great and rapid changes of temperature which take place inside the cylinder of a gas engine, one would expect to find in working considerable distortion, and therefore much of what the author had believed to be wear might really be due to this cause.

The author referred to the methods which had been adopted to reduce this wear, and amongst these he had specially mentioned tail rods. These large horizontal pistons, supported by tail rods, had very largely gone out of fashion in the case of steam engines. He could hardly believe that such methods would be the universal practice with gas engines. If that were so, surely the way to get over the trouble of the wear of pistons and the troubles with tail-rods, which after all were only makeshifts, or at any rate suitable for one set of conditions only, was to strike at the root of the problem at once, and realise that radical changes in the design of gas engines must be faced in the future. Surely the experience of the steam engine would tell us that, except in special cases where slow speeds and large engines were desirable for special reasons, the cure for this trouble would probably lie in the use of vertical engines running at high speeds, and the possibility of variation of speed. Of course, he did not mean to say that the vertical engine would be universally applicable, nor that there was not wear in a vertical engine, but what he meant was that, until the gas engine was free from the limitations of speed and design which at present surrounded it, it was not likely to be an alternative to the steam engine under all conditions of working.

The account which the author had given of the way in which the rod of an engine had been turned, so as to counteract the bending at different points of the stroke, was delightfully interesting, and it showed the shifts to which one was led when one had to deal with these very heavy slow moving masses. It was extraordinary that, in order to avoid the wear of the cylinder and piston, one should really be driven to dealing with the rod in the way the author described, that is in order to reduce wear at one place, to enormously increase it at another. He would like to ask, even at the risk of repetition, whether the future was not going to lead to much higher speeds even than those used in the case of the steam engine? Was it not possible that they would find some of the troubles at present experienced from over-heating with two-cycle engines would not be increased by running the engines very much faster, while it would afford the possibility of altering the period of ignition just as they did in the petrol engine, and so getting a much more clearly, definitely and beautifully regulated engine with increased efficiency if properly controlled. At the same time the engine would become much smaller, and probably the trouble from very high temperatures would be reduced. If with this was coupled a more extended possibility of regulating the charge by throttling, which was now becoming more common, he believed that the steam engine would have a very serious rival indeed. He could not help believing that it was in that direction that advance would really be made.

One further suggestion that had occurred to him (when the author spoke of the troubles with packing) was, would it not be possible to get over this difficulty by the use of a fluid packing under pressure? A small leakage of steam into the cylinder would not matter, indeed suggestions have been made for the use of steam mixed with gas. There was, of course, the Vogt engine, in which water was put right inside the cylinder, instead of putting it outside in the jacket, and in this way a most wonderfully interesting and efficient arrangement was obtained. The water was pumped in under pressure and kept circulating by an auxiliary pump, and, by increasing or reducing the quantity of water inside the cylinder, the compression could be increased or reduced to a nicety to suit the charge, and therefore a nearly perfect regulation of both charge and explosion could be obtained. The efficiency obtained with a small-sized engine on this system, with which the speaker had experimented, was remarkable.

The author had referred to the utilisation of waste heat in the gas engine. Of course, that was a very interesting and important question, but he must confess that, in his experience, he had found the occasions on which the exhaust gases could be used for really useful purposes were very limited. If it was sought to utilise them on all occasions artificiality would be introduced, with consequent losses much greater than the gain obtained. He did not in any way wish to discourage the utilisation of the exhaust heat where the conditions were suitable, but he wished to sound a note of warning against the idea that under all conditions it was wasteful not to use the heat in the exhaust gases. Where the conditions were favourable, it was bad engineering not to utilise them, and the author was perfectly right in drawing attention to the matter. He was not, therefore, speaking against the utilisation of the waste heat. He only meant to point out that it was not universally possible.

Mr. W. Pollard Digby said that the author had given them a paper of very great interest. They wanted to know far more of the subject of the working of internal combustion engines. They had very little that was absolutely official respecting the breakdown of engines of this and other types. The author had mentioned in the paper a great many of the points of trouble. It was curious that the author in the opening paragraph deprecated the conservatism of the consulting engineer. He thought, however, the author himself had justified that conservatism in the course of his paper. They heard of broken piston rods, broken pistons, pre-ignition, and trouble with the packing. Engineers some four years ago were assured that the Körting gas engine was a commercially successful machine. Now, Mr. St. George Moore told them that the engines of the particular type which had been used during the last eighteen months were much to be preferred to those with which he had had actual experience, but were they sure that they had got to the end of the stream of difficulties ? Speaking from a rather extensive series of reports which passed through his hands last autumn, he was rather inclined to disbelieve that they were nearly at the end of the troubles of the internal combustion engine. It had been hailed as a triumphant success time after time. About twelve years or so ago there were one or two municipal electric lighting installations put down in this country, and very remarkable fuel costs were published. Later on, when consulting engineers in Victoria Street were not so intimately concerned in the management, the borough electrical engineers took very good care that all their extensions were with steam-driven machinery. That was the experience of ten or twelve years ago. The experience of a couple of months ago was that, in a very large installation in South Africa, as the engineering papers of last week stated, a certain city council had voted 11,000*l*. for steam engines to replace the existing gas engines. Of course, as to that particular type of gas engine in the South African installation, he did not at all share the author's rather commendatory opinion of it. He (Mr. Pollard Digby) had seen an engine of this pattern at work some months ago at Glasgow. The author said that the engine was well balanced. That was so far as the balancing of the moving parts of the engine was concerned, but, if one went beyond that and considered the turning moment, the turning moment of any double-piston engine in which the explosion of the charge took place between the two pistons must be very bad indeed. Anyhow, they knew that there had been cases of broken crank shafts in this particular installation.

Passing on to dynamos driven by gas engines, the direct current machine was a very simple matter. When working in parallel one experienced even less trouble, and as Herr Reinhardt told them, at the Iron and Steel Institution last year, the running of alternators in parallel was a thing which could be quite easily effected, but, after the experience in South Africa where the alternators were driven by gas engines, he did not think this was the case. Then there was another point which was a purely electrical one; that was the trouble of gas leakages in the room. He was not speaking of cases of gas poisoning, but the fact of gas leakage on the electrical generator machinery. He once saw a 300-kilowatt dynamo completely laid off by the failure of a commutator through gases which had leaked into the room, corroding the copper. He was rather fortunate in seeing that machine a week before it broke down and a day after. It was a wonder that the conductors of the armature had not been corroded to such an extent as to require re-winding.

Then too, the question of lubrication was a difficult matter. It was very easy to over-lubricate an internal combustion engine. If they over-lubricated a steam engine it did not matter very much. Of course, it was extravagant and they had to get the oil out of the feed-water; but when they came to over-lubricate an internal combustion engine, it meant choking up the cylinders with carbon; the carbon becoming red hot and causing pre-ignition or leading to explosions in the exhaust pipe through pieces lodging under exhaust valves.

Mr. W. A. TOOKEY said that he was very decidedly with Mr. Digby in commending British gas-engine builders for keeping to the type of engine with which they were familiar. It had occurred to him that the whole trend of the paper had been to show that some continental types of engine which English engineers heard so much about, were not, after all, so very much better than, if as good as, the British gas engines of the four cylinder open type which were sometimes derided. He had seen within the last month some of the large British made engines of the Cotter type of from 250 to 750 H.P. He was sure that nobody watching them could ask for any better working engines. He was referring particularly to the six-cylinder three-crank Westinghouse vertical engines of 300 and 750 H.P. and also to the 500-H.P. Crossley horizontal gas-engine with two cylinders tandem. He had seen both of these engines working very smoothly indeed under good loads.

The author seemed to disparage the Körting engine. It seemed that "Working Experiences with Körting Engines" would have been a better title for the paper, as there was very little about any other type than the Körting engine in the pamphlet.

After all, was the Körting engine quite as bad as the author implied? Only that day he had had the opportunity of seeing a 600-H.P. Körting engine working very satisfactorily, which had been in daily use for over eighteen months. The piston and valve had not been cleaned for a great many months. It worked from Monday morning to Saturday evening without a breakdown and the only attention usually necessary to be given to it at the week-end was about half an hour's examination. This proved that even a Körting engine could go for eighteen months without trouble. This brought him to another point.

People forgot that in the designing, building, and working of an engine there were a great many minds employed, and, apart from the fact that practical considerations for pattern-making and foundry-work occasionally interfered with theoretical intentions, and made a compromise inevitable in the arrangement of vital parts, after all, it was the man that worked the engine who was responsible for getting out what the designer meant should be got out of it. There was more in the personality of the gas-engine attendant than was generally allowed for. He wished to insist on that point. The engine might be good or bad, but it was the attention which an engine received in practical work which made or marred its success.

White metal packing of the piston (already alluded to by Professer Capper) was mentioned on page 122 of the paper, It seemed very curious why the author should commend a piston "properly shod with white metal" when, on page 123, they were told, "white metal will not stand any heat, wears away rapidly, and is easily broken." In the 600-H.P. Körting engine he had previously mentioned, no special precautions had been taken to obviate the wear of the piston beyond particular attention to the proper internal lubrication of the cylinder.

Then with regard to lubrication, he would ask whether the dropping of a few drops of oil on the top of the piston was really a proper and efficient way of lubricating a gas-engine piston and cylinder. Would it not be better, instead of putting a copious supply of oil on the piston, and hoping it would flow to the sides and bottom of its own accord, to actually put it where it was wanted by forced lubrication? This might mean a little complication of pipes to supply the oil in places, spaced radially and longitudinally around the cylinder, but those pipes need not be of large size, for as long as a small amount of oil was on the right spot, that was the main thing. Again, did they not have rather too large an orifice for the oil to enter the cylinder? Would carbonisation take place if the apertures in the cylinders were much smaller? It seemed to him that if the openings were smaller, they would be entirely filled up with the oil due to forced lubrication, and this would render them much less liable to become blocked and the oil carbonised. He would ask the author to let them have his views upon that point.

The effect of position of the sparking-plug on the ignition of mixtures referred to on page 124, was also very interesting. At the time of the experiments, as the author pointed out, the engine was running under only a two-thirds load. It seemed, however, from the diagrams as if the mixture was rather weaker than the two-thirds load would suggest, and it was quite possible that they would get some erratic firing, if the engine was being supplied with, not a poor gas, but a poor mixture. Probably the air was not properly proportioned to the quality of the gas.

He had had an opportunity of reading the paper before he saw the Körting engine to which he had already referred, and had tried the experiments which the author had pointed out about the differences between the end plug and the side plug. Upon casual observation on this particular engine at any rate no difference in working could be detected, and he, therefore, thought that the proportions of the gas and air in the mixture had a great deal to do with the results noted by the author.

The remarks as to pre-ignition were also of great interest. Pre-ignitions were very distressing, if not very harmful; but the author had said that "if everything was right the pre-ignitions should not occur more frequently than once every two or three hours." He should like to ask him why they should not occur more frequently, and why they should occur at all? It seemed to him that the author had some excuse for them, and he should like to know what the excuse for pre-ignition was. It seemed to him that the main cause of pre-ignition, and the main cause of gas-engine trouble, was due to the gas served to the engines. They heard so much said to the effect that the gas must be clean, and that very special precautions were taken on the Continent to clean the gas. But frequently, although they cleaned the gas most thoroughly, they took in air with all the impurities which it might contain. When they had some better methods of lubricating the cylinder, and of cleaning both gas and air, they would find, he thought, that the large gas-engines would work with much more reliability, and that pre-ignitions would be unknown.

Mr. ARTHUR VALON thanked Mr. Moore for his very clear statement of the difficulties which he had found in running a large gas engine, and the methods which he had taken to overcome them. As a consulting engineer who had been responsible for putting in steam engines where gas engines might conceivably have been used, he thought that the statements in the paper were a sufficient reason for the conservatism of consulting engineers apart from the reason which Mr. Moore had given in his paper. The large gas engines of the present day were neither so reliable nor so simple as large steam engines, and although the fuel efficiency might be higher, he did not think it always was. Against the fuel efficiency they had to set the increased supervision, the increased maintenance, and also the increased initial outlay. He believed that the gas engine was destined to be the motor of the future and probably of the near future, but he did not think that the large gas engines at the present time could compare with a steam engine of corresponding size.

After having charged the consulting engineer with conservatism, the author similarly charged British manufacturers, because they had developed in the larger sizes, the same type of engine as had been successful in smaller sizes. By that he understood the author to mean that they had kept to the open cylinder and trunk piston, the Otto single cycle and had duplicated the small cylinders. But apart from conservatism those three points helped considerably towards the solution of the chief difficulties which were met with in large gas engines. One of the chief points was to keep the charge cool, and the Otto cycle, and open cylinder and the small cylinders all helped towards that end. The evil effect of a large and long cylinder, the difficulties of keeping the cylinder tight, cracking, and so on, were shown in the paper, and those features of the Körting engine which were its weakest features, were just those which were avoided by sticking to the small and open cylinder and the Otto cycle type.

The author said that he had made some experiments with regard to the different methods of governing large engines. He should like to know if Mr. Moore had had any experience as to the relative efficiencies of the different methods of governing. Experience seemed to show that with small engines the hit-or-miss governing was the most economical, and that the throttling of the gas was the least economical. Of course, with large engines the hit-or-miss was hardly applicable. He should like to know how the two other methods compared—whether there was so much difference between throttling the mixture and throttling the gas, as there was in the small engines. Then would the author say what compressions were used for his engines.

With regard to his experiments as to the effect of increases in the calorific value of the Mond gas used, could the author say within what limits the constituents of the gas varied? He knew that some persons were rather surprised that large gas engines could be run satisfactorily with coke oven gas because of the larger proportion of hydrogen, namely, 41·8 per cent. But he (Mr. Valon) would point out that in Mond gas, although the proportion of hydrogen was only 26·6 per cent. of the total gas, still, if they took away the nitrogen and dealt with the combustible constituents only, they would find that the proportion of hydrogen was 46 or 47 per cent.

He was very much interested in the experience with Mond gas because that gas was, he believed, the only gas besides coal gas which was supplied from central stations. There were many advantages in a gas supplied from a central station, but he did not think that it could be made a commercial success to supply any gas which had so large a proportion of inert matter as Mond gas or producer gas. Coal gas engineers up to the present, really had not had a chance. They had been handicapped by having to keep a high illuminating power which, now that the incandescent mantle was in vogue, was not at all necessary. There was a large amount of research going on in the gas industry in the hope that Parliamentary requirements as to illuminating power would, in a comparatively short time, be abolished. They hoped that with improved methods of carbonisation they would be able to produce a modified coal gas which, while still equally useful with the present gas for lighting purposes with the incandescent burner, could still be sold at such a price as would enable it to be used for gas engines generally. He thought it was in that direction that they must look for the ideal fuel of the future, if it was to be distributed from central stations.

Mr B. S. Giles thought that some parts of the paper were apt to be a little misleading without a few words of explanation. With regard to the conservatism of English engineers, he thought that Mr. Moore's remark was quite just. English engineers had had the experience of what could be done on the Continent. It was not as if the whole subject of gas engines was an altogether new one. If engineers chose to put aside the experience gained on the Continent, they would never get any experience at all. This, he thought, would be wrong and would not conduce to the greatest progress. Whilst English engineers were debating as to whether they ought to do this or that. and whether they ought to take upon themselves the responsibility of putting down large gas engines, the more enterprising manufacturers were really using such engines and making money by them. Mr. Moore had given a very bad account of the Körting gas engine, and although he mentioned in his paper that the experience referred to was gained eighteen months ago, his statements might be very misleading. Readers of the paper might not be aware of the fact that improvements during the last eighteen months had been very considerable, and as a matter of fact, all the difficulties which Mr. Moore mentioned had been overcome. As regards the fault of sticking, attributed to the bye-pass governor valves, it was simply a matter of seeing that the gas was perfectly clean. It was not a fault which was inherent to that type of valve at all.

With regard to the power which Mr. Moore said was required for working the charging pump. that seemed to him (Mr. Giles) to be rather extraordinary. On page 119 Mr. Moore said, "The power to work the charging pumps varies from 12 to 15 per cent. of that indicated in the working cylinder." Well, suppose they took the mean of those two figures and said 13½ per cent., then Mr. Moore continued, "The said efficiency must be less than that of the four-cycle type. The combined efficiency of a Körting engine and dynamo was not usually more than from 70 per cent. to 75 per cent." Let them take the mean of those two figures and say 72½ per cent. This meant that there was 13½ per cent. lost on the charging pump, and 14 per cent. lost in all the rest of the engine and dynamo put together. He thought that obviously there must be something wrong in these figures.

With regard to the question of the piston, it was quite correct that in the last eighteen months the piston had been improved.

The statement about the cracking of the cylinder head was another one which would cause misunderstanding. There was a little trouble in the early stages of the cylinders, but there was a special reason for that, viz. that in the early days it was necessary to obtain some of the castings from abroad, and some of these castings were too soft.

One of the speakers alluded to the fact that during the last eighteen months a Körting engine had been run from the first thing on Monday morning to the last thing on Saturday night, and that it had been examined on the Sunday and started again on Monday morning. That, he thought, was a very good record.

Mr. Hal Williams said that the author commenced with the remark that most of the literature concerning gas engines was written from the manufacturer's point of view. He should like to know from what point of view the author had written. He should say that the paper was excellently calculated to make people who contemplated putting in gas engines adopt the advice given by *Punch* to people about to marry—"Don't."

He did not think the author did justice, either to the Körting engine or to other large engines, and he was inclined to think that the Körting engine was not quite as black as it had been painted.

The author had stated that in his opinion scavenging was an open question. His (Mr. Williams's) own experience was that Professor Grover, of Leeds, was quite correct in the contentions that he laid down some time ago. Those were, roughly, that greater pressures could be obtained when a proportion of the cylinder was occupied by residual gases instead of excess air; that an explosive mixture could be obtained when 58 per cent. of the cylinder area was occupied by the spent gases, provided that the volume of air was not less than five and a half times the volume of town gas present, and that the use of exhaust gases instead of air delayed the propagation of the flame in the cylinder. He (Mr. Williams) had found in his general experience that the use of spent gases in the cylinder was a decided advantage. He had frequently found in the Otto cycle engine—he spoke of an engine governed on the hit-or-miss principle—that when the engines had been firing up to the maximum capacity, the mean effective pressures obtained from the charges were every bit as good as, if not better than, the mean effective pressure of a power stroke following an idle stroke. That could often be plainly seen from a Mathot continuous record.

Some of the speakers had said that it would be an advantage, if the horizontal engine were replaced by the vertical one. There was no doubt that from the point of view of space and cost it would be a great advantage; but if an engine were built vertically in order to get over the trouble as to space and cylinder wear, a great many other difficulties would be introduced which had not yet been successfully overcome. The vertical engine had complaints which were entirely distinct from those of the horizontal engine, and so far as his experience went, they had prevented its being in any way a reliable or successful engine. There were, of course, instances in which vertical engines worked extremely well—on a test bed or for a few months—but an engine of any sort was of no good to anyone who wanted power, unless it were capable of working successfully without undue wear and tear month in and month out. That, in his opinion, was what the vertical engine at the present time could not do.

The wear of the cylinder was extremely interesting, because they were told that the wear took place when the piston was shod with white metal—if it really was white metal—which he doubted. One was inclined to ask, what would have happened if the piston had been arranged in the ordinary way.

The points which lay round the question of the magnetos were also extremely interesting. Körting, he believed, was the first maker of large engines to use two magnetos. He thought it was now pretty well accepted that the sparking plug was better near the piston than at the end of the breech. If it was put at the end, there was apt to be moisture deposited on the contacts from the compressed air or entering gas. If it was put further towards the piston, there would be a much more rapid propagation of flame, and there would not be the lingering fire, with no pressure and pre-ignition. The solution of the question which the author appeared to find puzzling seemed to be that the magneto nearest the piston would most effectively fire the charge, and it would, therefore, easily account for the phenomena which he noticed.

He agreed with Professor Capper on the question of waste heat. If the heat was not wanted, it was much better that it should go into the atmosphere than that a quantity of expensive apparatus should be applied in order to save it. The author suggested that the steam generated from the exhaust of the engine should be used to supply producers, and that, therefore, no boiler would be required. He presumed that he meant to start in the first instance by using a small vertical boiler, which would be thrown out of use as soon as the exhaust boiler got to work. Obviously, .the producers must start somehow. His experience in connection with horizontal engines was that the best arrangement was a combination boiler, which could be stoked with coal, and which could be heated by exhaust gases at the same time. If there was a furnace in the boiler, the stoker would be able to keep the steam head constant, irrespective of the load on the engine.

The Mond gas trouble appeared to be rather a characteristic of that gas. It seemed to be a fact that they got a much cleaner gas, and one much freer from tar, if the tar was condensed before the gas was brought into contact with water. That, of course, was done in Wilson's plant; and although they got considerable quantities of tar they did not have the same trouble, and did not require such large scrubbers, or so much water as they did with gas plant; the cleaning apparatus of which consisted almost entirely of water scrubbers.

As he had previously said, he did not think they ought to allow the public to think that with every gas engine put down they had to expect, as a matter of course, back fires, broken piston rings and the other evils referred to. He did not think that was right, because he and others had had ample experience of gas engines which were working perfectly satisfactorily. His own idea of the matter was that at the present time the two-cycle engine was not what might be considered a reliable commercial engine. The single acting Otto engine approached much more nearly to that definition. He had installed many single acting Otto cycle engines, and though he did not approve of hit-or-miss governing, they worked quite satisfactorily with a load which was fairly constant, and which did not require a particularly fine cyclical variation.

There would be no difficulty at all in putting down installations of gas engines of any size, but, to his mind, the cylinders should be small, and power should be got by multiplying their number. There is no reason at all why they should not have 400 horse-power gas engines with four cylinders of 100 horse-power, or three of 130 horse-power. That would be an extremely satisfactory commercial engine.

Mr. R. A. Bell welcomed the paper for two reasons. In the first place it justified the opinion which he had held for a long time. The late Sir Frederick Bramwell prophesied that when the last steam engine was sent to South Kensington Museum the two-cycle gas engine would be there with it. The other reason was that it justified him in the opinion that the vertical gas engine had certainly a great many points of advantage over the horizontal type.

The question of the wear on the bottom of the cylinder was very well met in the vertical engine, probably better than it could be in a horizontal engine; and that was by putting the centre line of the cylinders on one side of the centre line of the cranks to get over the extreme obliquity of the connecting rods. That would be awkward in the horizontal engine, and quite impossible in a double acting engine.

As to Mr. Williams's remarks with regard to vertical engines running with a continuous burden, he might say that he was connected with the manufacture of vertical engines, and he was glad to be able to report that they were able to do everything the Körting engine could do. In his experience the engine was started on Monday morning, and it ran until 10 o'clock on Saturday night, and that had been done for two and a half years, which, he thought, was really a proof that the vertical engine was quite capable of looking after itself.

Mr. E. G. BEAUMONT wished to ask two questions relating to the remarks of earlier speakers. Mr. Tookey, in describing the performance of a large Körting gas engine, stated generally its performance and the small amount of trouble that it gave, but he did not give any particulars about the gas consumption, a matter of considerable importance in connection with the type of engine to which the author referred in his paper. Mr. Hal Williams referred to the question of governing. He should like to know through what range of load they were able to get the nicety of governing of which he spoke, because it would seem that the range would be limited; or more limited than when the combination of throttling and hit-or-miss governing was used.

He should like to ask whether the large amount of cylinder wear shown by the figures given in the paper in connection with one of the engines described, was greater in the track of the piston bearing piece, that is whether there were any direct signs that it was wear due to the travel and weight or efforts on the piston, or whether it was due to other causes.

Mr. L. F. DE PEYRECAVE said that Professor Capper in speaking of sizes had compared gas engines with steam engines. He thought that the Professor had neglected the boilers of the steam engines which, of course, took up a very considerable amount of room. When the two were taken together, the gas engine compared very favourably with the steam engine. He also referred to the leakage past the piston and tried to account for the loss of gas in the two-cycle engine on this head. In point of fact, the leakage was proportionally less with a large cylinder than with a small cylinder. It could not account for as much as 20 per cent.

Professor Capper also referred to the speed of the gas engine, and said that it should be increased. Of course, this was limited by the piston speed. They could obtain only a certain piston speed. The rate of propagation of the gas flame was also limited.

There were some very interesting features with regard to the point of ignition. Mr. Williams remarked that the later the ignition, the lower the initial pressure, and the greater mean effective pressure. This he had often noticed, but at the same time he thought that it was due to indicator error and not to increased power. He had tested it several times, and invariably a greater power had been obtained with a nearly vertical explosion line and consequent high initial pressure, and he thought that most people could confirm the fact. The indicator, when the change of motion of the pencil is very slow, will give a greater effect due to friction than when the motion was faster. With a sharp explosion there was a very sudden drop, and the indicator pencil followed the line very closely providing the speed was not excessive. When they had a lower explosion, the pencil dropped comparatively slowly and had a tendency to lag. It kept the highest line, and there was consequently a greater mean effective pressure.

The following communication from Mr. R. F. Thorp, M. Inst. C.E., was read by the Secretary.

The author seems to have experienced very serious troubles both in wear and tear of the working parts of the engines on which his trials were made, such as cracked pistons and cylinders and also in regard to pre-ignition. These troubles may be sometimes due to the bad design of engine details and the use of unsuitable materials, but I think it is only fair to the many English and Continental gas engine makers to say that these faults are the exception and not the rule.

In the cases referred to in the paper, if we first study the analysis of the gas used, I think it will not be necessary to seek elsewhere for the cause of the troubles. In the gas used there was 26·6 per cent. of hydrogen present and this is quite sufficient in my opinion to account for all the troubles experienced.

As is well known, hydrogen produces a very violent explosion when ignited, and to realise the effect that a gas containing a large percentage of this ingredient will produce, we may consider the conditions that obtain in another branch of our profession.

This comparison I feel sure Mr. Perry F. Nursey (who is an expert in this branch) will appreciate, namely, the use of explosives for the removal or destruction of rocks, etc. It is well known to all engineers who have had experience in this class of work that different classes of explosives cause different effects, and are each best suited to effect the special results required in any particular case. For instance, if we wish to shatter a hard piece of rock, dynamite will do what we require, but if we require rock for building purposes and therefore merely wish to split it up without shattering it, then undoubtedly a slow burning powder will give the best results.

Now in the case of the gas engine we do not desire to drive the piston from one end of the cylinder to the other with sledge hammer blows with the consequent shattering effect, we merely wish to push it as steadily as possible from one end to the other, and to effect this object a comparatively slow burning explosive is the one best suited for our purpose. It is therefore evident that a gas low in hydrogen (say 2 per cent. to 6 per cent.) and having a calorific value of 110 to 120 B.T.U. will be the very best that we can use. By the use of a power-gas of this description, the troubles, of breakages in the working parts of the engine and of pre-ignition experienced by the author of the paper, can be satisfactorily eliminated, provided the engine used is designed and made by one of the many excellent makers of modern gas engines.

The great troubles due to the use of power-gas high in hydrogen are very much more marked in the case of engines of large capacity, nevertheless they do exist, but to a smaller extent, in the case of the smaller engines. In all cases the gas must be thoroughly well cleaned and cooled, and this does not seem to have been done in the cases referred to in the paper.

As is well known by the best authorities on the subject, all the most successful large engines (to the extent of thousands of horse-power) are working with gas, the composition of which is low in hydrogen and high in carbonic oxide.

The following communication from Mr. William Schönheyder was read by the Secretary:—

I have read with interest Mr. C. St. George Moore's paper on large gas engines, especially those sections which relate to the wear of cylinders and the cambering of piston rods. It will be remembered by some of the Members that in 1878 I read a paper before the Society on "Equalising the Wear in Horizontal Steam Cylinders." That paper, which will be found in the Society's Transactions for the above year, contains the following description of my method of dealing with the cambering question:—

"The method which the author adopts for carrying the piston is to prolong the rod through the back cover, as has been done before, and to give it a camber of the desired form and extent in the following manner: The deflection of the finished piston-rod when supported at each end, and when weighted at the centre with the piston, having been first calculated, the piston-rod is given approximately, while in the black state, a curve or camber of this amount. It is next placed in the lathe between centres, a bearing is bolted to or formed at the centre of it, and the bearing is next sprung down into a plummer block on the lathe bed, and which has been placed central with the extreme lathe centres. The turning is now proceeded with in the usual manner, but by preference with two tools travelling in opposite directions. After having finished the rod and removed it from the lathe, it will be readily seen that it will have just the correct form of camber, so that when weighted with the piston and placed in the cylinder it will assume a straight line, and will not throw any load either on the glands or the cylinder.

"To facilitate the manufacture, the author has designed a special collar for forming the central bearing; and when very large rods are required to be made with the camber, the author employs a specially designed lathe in which the rod is stationary and the tools revolve outside the rod, at the same time that they receive a motion longitudinally to the rod. By this arrangement the varying side strains on the lathe bed, which necessarily exist if the rod revolves, are entirely eliminated."

I may add (1) that it is not impossible to turn the rod to the exact curve required, (2) that it is simpler to revolve the rod in the usual way, provided the lathe is strong enough, and (3) that it matters very little if in making the rod it is a trifle more or less deflected than it should strictly be.

At the time of reading my paper I found great difficulty in getting people to thoroughly understand the subject. My invention, however, was successfully and profitably worked in Germany.

The author, in replying, said that Professor Capper had expressed a wish to know what was the largest gas-engine yet built. So far as the author was aware, the largest engine yet constructed, was one of 4000 H.P. of the Nürnberg type, built by Messrs. Haniel and Lueg. This engine has four double-acting cylinders working on the four-stroke cycle.

With regard to the leakage of gas into the exhaust, it was not very likely that this was in any great part due to leakage past the piston rings, as the amount lost did not seem to vary much with the condition of the rings. A heavy leakage past the rings would certainly tend to upset the stratification of the gas during the compression stroke, but at this stage in the cycle the stratification was not of very great importance so far as the Körting cycle was concerned.

The white metal used for taking up the wear of the piston, was of the ordinary kind used for bearings, and no trouble was experienced in keeping it cool, unless all the piston rings were broken. Except in this case, this part of the piston is well away from the flame, and consequently keeps quite cool.

Concerning the wear of cylinders, it was well known that a large amount of temporary distortion took place while the engine was running, but how much of this distortion was likely to remain after the cylinder had cooled, was a matter open to discussion. If this permanent distortion did exist, it would be in the direction indicated by the figures given in the paper.

Professor Capper asked whether a fluid packing under pressure would be possible for gas-engines. The author considered that the principal difficulties would be, firstly, the high pressure—nothing less than 400 lb. would be of any use—and also the fact that a double metallic packing would be necessary, one on each side of the steam space. No steam could be allowed to enter the cylinder before starting the engine, or it would be impossible to get an explosion.

Mr. Pollard Digby had referred to the effect of gas leakage on the electrical generating machinery. The author had found that the products of combustion of Mond gas had a very rapid oxidising effect on any exposed copper, or other metal containing copper, such as brass or gunmetal. This action was evidently due to the very small percentage of sulphuretted hydrogen always present in the gas, which became sulphur dioxide after combustion. The author had found that if there were any considerable leakage of burnt gas into the engine room, all exposed copper or brass turned blue in the course of a few hours, and any brass or gunmetal used for packing or other purposes where it was brought into direct contact with the burning gas, was very rapidly corroded away. With regard to the electrical machinery no trouble had been experienced after three years' work, the insulation being presumably sufficient protection. The commutators were of course cleaned frequently, which was quite sufficient to prevent any serious corrosive action from taking place. The unburnt gas had no corrosive effect.

Mr. Tookey had referred to the effect of the position of the igniter on the running of the engine. The author thought this could be judged only when the engine was driving a dynamo, as then the power could be directly read off on the ammeter, whereas if the engine were driving machinery, the only effect noticeable would be a slight alteration in the speed, which would not be so easy to detect.

The same speaker also asked why it was necessary that pre-ignitions should occur at all. To find out the cause of pre-ignitions was one of the most puzzling problems that those in charge of large gas-engines had to deal with, and the author doubted whether anyone who had been in that position would attempt to answer the question.

Mr. Valon had objected to gas engines on the score of increased supervision being necessary. The author had found that except in very large sizes, gas engines ran with as little attention as steam engines, if most of the oiling was done automatically.

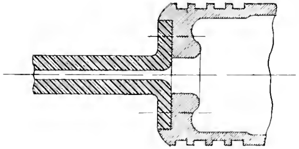
With regard to governing, the author had made no experiments to ascertain the relative economy of the different methods, but he thought it was generally conceded that the hit-or-miss method was the most economical. For large engines with comparatively small cylinders, if a very regular turning moment was not required, he believed this method would be found quite satisfactory and reliable, a separate governor being provided for each cylinder. If the engine had six cylinders the irregularity would not be very great, as only one cylinder would cut out at a time. The author had found the hit-or-miss method quite satisfactory for direct current work on 200 H.P. engines with two cylinders. If the engine were governed by throttling the gas alone, he considered that the best economy could be obtained by advancing the spark as the mixture became weaker, and if this were done he thought there would be not much difference in economy between this method and throttling the mixture.

The compression used in the large engines mentioned by the author was 140 lb. per square inch. He considered this rather on the high side for use with producer gas. In the 200 H.P. engines mentioned above, the compression was only about 80 lb. Pre-ignition in these engines was practically unknown, and the reason for this low compression was evidently to avoid having to use water to keep the piston cool. The hydrogen in the gas used varied in ordinary working from 25 to 28 per cent., and the marsh gas from 2 to 3½ per cent.

Mr. Giles had emphasized the fact that the Körting engines referred to in the paper were eighteen months old, and that since then many modifications had been introduced. This was certainly the case, but at the same time it must be remembered that there had not been time for much working experience with engines of much more recent date than these. Messrs. Mather and Platt had so revolutionised the design of this engine that it could not be compared with the Körting engine as designed and built on the Continent, and the author believed that their newer engines, in which the size of the cylinders had been kept down, had attained very much better success in this country than the Continental type. Mr. Giles had also remarked that no trouble would be experienced by the valves sticking if the gas were kept perfectly clean; this was no doubt true, but in the case of Mond gas, as the author had tried to point out in the paper, it was a matter of very great difficulty to get it thoroughly clean.

In reply to Mr. Beaumont, the author considered that the wear of the cylinders was due to a very large extent to the friction of the piston rings, in view of the fact that the wear at the bottom of the cylinder was not very much greater than at the sides and top. It was possible that the rings in the engines in question may have had too much spring.

WORKING EXPERIENCES WITH LARGE GAS ENGINES.
BY C. A. ST. GEORGE MOORE.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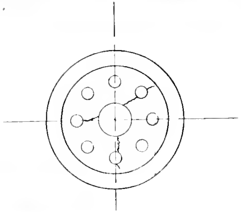
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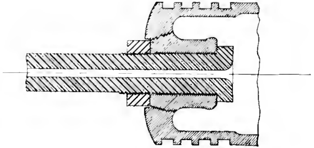
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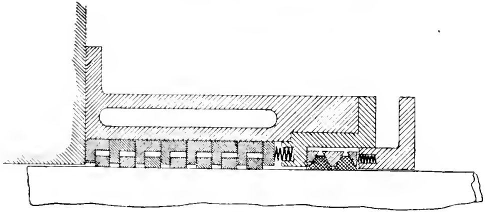
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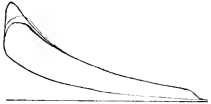
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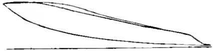
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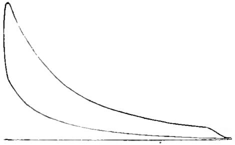
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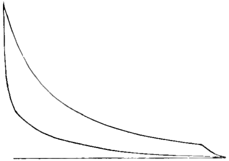
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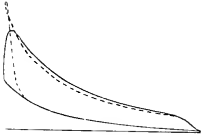
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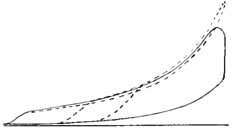
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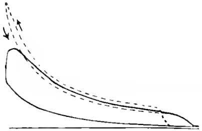
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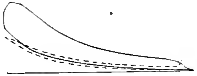
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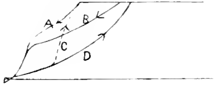

Fig. 13.

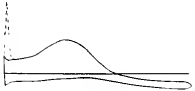
Fig. 14.

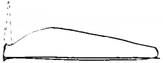
Fig. 15.

VACATION VISITS.

Owing to the death of the late Secretary, Mr. Perry F. Nursey, only two visits were made during the vacation of 1907. Brief notices of these appear below.

Honor Oak Reservoirs.

A visit was made by the members of the Society of Engineers, on Wednesday, June 19, 1907, to the new reservoirs of the Metropolitan Water Board, in course of construction at Honor Oak, and of which the following is a description:—

These reservoirs will contain nearly sixty million gallons of water, and will probably be the largest covered reservoirs in the world. They are being constructed near Homestall Road, Honor Oak, Camberwell. The construction generally is of brickwork and concrete, with division walls separating the reservoir into four divisions. The longitudinal centre wall runs approximately north and south, so for the purpose of reference the reservoirs will be known as the north-east, north-west, south-east and south-west.

The outside walls of those portions of the south-east and south-west reservoirs which are below or level with the natural ground represent in plan a series of flat arches so as to resist earth pressure. The north-east and north-west reservoirs have concrete retaining walls, faced with brickwork. The centre dividing walls are also arched in plan, and are practically double walls filled in between with concrete, the thickness varying from 6 feet in the centre of each bay to 10 feet at each buttress.

Around all the outer walls and the division walls buttresses in brickwork project into the reservoirs. These buttresses are carried up solid to the drums on the roof covering, and in themselves form substantial counterforts to the walls. The floor of the reservoir is of concrete, and its surface will be formed with curved inverts groined so as to form bases from which the brick piers carrying the roof will rise. This inverted floor will be finished with $\frac{3}{4}$ inch of cement rendering to a smooth polished face with a drain down the middle of the invert, draining all the water into the collecting channel.

From each base a brick pier is built, which is continued up 14 feet, where jack arches are turned, connecting each pier north and south. From the top of the wall thus formed, the drums or covering arches spring. The drums form a series of tunnels running north and south. The haunches of the arches are filled with concrete, on the top of which clay puddle will be placed, followed with earth and, finally, soil. A drain with open joints is laid on the surface of the puddle for the purpose of draining the top of the reservoir. A puddle wall 3 feet in thickness extends all round the outer walls, and is keyed into the clay, thus making the work watertight.

At the centre of the four reservoirs where the division walls intersect will be the central well, from which the charging and emptying will be directed. All the opening valves—42 inches, 36 inches, and 30 inches—will be arranged round the well, and worked by means of headstocks from a gallery running round the well. By means of special connections, it will be possible to work each or every reservoir at the same time, without interfering with the others. Above the central valve well will be a valve house, in which the electrical recording indicators will be arranged. When the works are completed, the tops of the reservoirs and the slopes will be soiled and sown with grass seeds.

The bricks used in the construction of the reservoirs have all been manufactured by the Southwark and Vauxhall Water Company, and later by the Metropolitan Water Board, from the excavation. Not only has the material been utilised in the making of the bricks, but the ground has been excavated on the site of the reservoir, thus reducing the quantity of earth to be handled by the contractor. It will be seen that the works involve the use of a large amount of concrete, in the production of which four of Taylor's one-yard concrete mixers are engaged. In these mixers each charge of material is measured and mixed separately, and each of the machines employed will mix 24 cubic yards of concrete per hour.

The whole of the works were designed by Mr. J. W. Restler, M. Inst. C.E., and are being carried out under his direction and supervision by J. Moran and Son, Ltd., as contractors, The estimated cost of the works, including pipes and valves, but exclusive of land, is, approximately, 170,000*l*.

H.M. Dockyard, Chatham.

By kind permission of the Admiral Superintendent, Vice-Admiral G. A. Giffard, C.M.G., members of the Society of

Engineers paid a visit to H.M. Dockyard, Chatham, on Wednesday, 25th September.

Assembling at the Pembroke Gate, the party divided into two, half going to the Central Power Station and Electrical Engineer's Department, and the remainder to the Constructive Engineering and other Departments.

The Dockyard dates from the time of Elizabeth; it was enlarged by Charles I., and after an attack by the Dutch Fleet under Van Ruyter in 1667, was improved by Charles II. Large extensions have been made from time to time, notably in period 1867–71, when new works at a cost of nearly 1½ million were carried out, and it is now one of the finest shipyards in this country.

The more modern parts consist of five docks and three large basins, connected by caissons. The walls of the basins are all 21 feet thick at base and about 40 feet high. One basin, nearest the Medway, has a mean length of 1270 feet, a width of 700 feet, and an area of 21 acres. This is mainly used for the reception of newly launched ships or those under repair after return from commission.

This basin is connected at its eastern end with another of the following dimensions: length 1245 feet, width 700 feet, and an area of 20 acres. The third basin is of irregular shape and has an area of some 28 acres.

A crane capable of lifting 160 tons, and sheer legs having a lifting capacity of 130 tons, and a number of smaller sheer legs and cranes with lifting capacity varying from 10 tons to 75 tons, are arranged around these basins.

The five docks vary from 457 feet to 656 feet in length.

The concrete for the construction of these docks and basins was composed of 1 of Portland cement to 12 of gravel dredged in the neighbourhood. The price of this gravel, which contains a good deal of loam, was 6*d*. per cubic yard.

In the Department of the Captain of the Dockyard several machines were viewed by the members of the Society, including, in the Sail Loft, a patent cutting machine adapted to cut wire rope, and a patent sewing machine, a band saw for cutting out canvas and fearnought dresses, and a machine for cutting the heads of flags.

In the Constructive Manager's Department, the largest of the three Smitheries contains over fifty forges, and the several Machine Shops in this Department are well equipped with the necessary machines and appliances for constructing ships cheaply and expeditiously, as well as many specially devised machines, among which may be mentioned those for file testing and engraving, while on H.M.S. "Shannon," which is now in course of construction, pneumatic riveting, chipping and caulking tools were seen in use.

Quite a number of interesting items were seen in the Engineering Manager's Department, including Boby's patent feed-water heater and softener, a CO_2 recorder, draught gauge, a cylinder and other grinding machines; a number of new automatic machines of various descriptions to supersede those previously used, the Wadkin wood-worker, a sand-papering machine, also a machine for separating brass from iron borings and brass from foundry ashes, a pneumatic moulding machine, oil metal-melting furnaces, an hydraulic tube-staving machine, and a compressed-air hammer.

The members examined several appliances in the Electrical Engineer's Department, and saw specimens of electrical heating and annealing, the application of the electric motor to driving, electro-plating, the photometer and the means of locating faults in armatures. After viewing the Central Power Station, the party returned by the 5.15 train from Chatham.

October 7, 1907.

JOSEPH WILLIAM WILSON, VICE-PRESIDENT, IN THE CHAIR.

THE CHAIRMAN (Mr. J. W. WILSON) said: Gentlemen, when you received the black-bordered notice of this Meeting, it conveyed to all of you what, I suppose, was known to most of the Members of the Society, that we had lost our good Secretary, Mr. Perry F. Nursey, and it is felt by the Council that this, the first ordinary meeting since his death, should not pass without reference being made from the Chair to the great loss the Society has thus sustained. Therefore, our President being in China, it has devolved upon me to say a few words on this sad subject.

Mr. Nursey was one of our oldest members; not the oldest, for there are several who have been a year or two longer in the Society than he had; but, to all intents and purposes, from his intimate association with it, we looked upon him as the father of the Society. As a matter of fact, if he had lived till this time next year, he would have been a member for fifty years. On Friday last, he would have reached the age of seventy-seven. I had looked forward to the pleasure of alluding to that fact in his presence on this occasion; and I may say that, in anticipating my being your President again next year, I hoped that one of the greatest gratifications of my year of office would be to take part in what we should have done to recognise his long service to the Society of Engineers during those fifty years.

You all, I think, know that Mr. Nursey filled every position that it is possible for a man to fill in the Society of Engineers. Not only was he one of the earliest members, but he was a few years later elected Secretary. Later on, he resigned the Secretaryship and was elected a Member of Council. In 1886 he became our President, and I well remember we all listened to his Presidential address with a considerable amount of pleasure, because it was written in his usual genial style; and, if any of you do not know it, you would find great pleasure in reading it through. He was subsequently elected Honorary Treasurer, on the death of Mr. Alfred Williams; and not many years ago, when there was a vacancy in the Secretaryship, he volunteered to again fill the position; and for the last years of his life he has been as good a Secretary as we are likely to see, knowing everyone, having all the affairs of the Society at his finger ends, and displaying so much energy and tact, that it was difficult to realise he had reached anything like his real age.

I think that it will be in the recollection of many of you, that my brother, speaking from this presidential chair just a year ago, alluded to the fact that Mr. Nursey had read twenty-four papers, one every two years, and that he hoped to be spared to read the twenty-fifth paper next year; and my brother feelingly alluded to his age, making use of the happy expression, that, like Moses, " his eye was not dim, nor his natural force abated "; and it was so to the end.

I am sure we all feel that we owe a great debt of gratitude to Mr. Nursey—as a Society, and personally—a debt which now we have no opportunity of even expressing, much less repaying.

We should, when our time comes, envy our old friend, for he was able to continue at work until within two or three days of his death; and, in the letter which I received announcing it, his son was able to say that he passed away quite peacefully.

Knowing what we do of Mr. Nursey, and of the sterling, honourable character which he always bore throughout a long life, we cannot help feeling that he carried out what was so well expressed by a great poet many hundreds of years ago, in a book which Mr. Nursey valued beyond every other. The poet said, " Keep innocency, and take heed unto the thing that is right, for that shall bring a man peace at the last."

The Council have done everything they can to express what is due to Mr. Nursey's memory. They were represented at his funeral, and sent a wreath, bearing the appropriate words " In affectionate remembrance of lifelong devotion." They have sent a letter of condolence; and—I am sure with your approval—have made a grant of 50*l.* to Mrs. Nursey by whom it was much needed. She has written a very grateful letter, expressing thanks, not only to the Council, but to all the Society, for their affectionate consideration and regard for her late husband.

Now, it seems to me—and the Council support me in the idea—that under circumstances of this kind, it would be well if we went a step further, and, *as a Society*, were to express our feeling of regret for the loss of Mr. Nursey, and our appreciation of what he has done for us, and our sympathy with his widow and the rest of his family. Therefore, I now propose to read you this, which I put forward as a proposition, and I hope that someone in the room—some old friend of Mr. Nursey—will second it.

"The President, the Council, and the Members of the Society of Engineers, at this their first meeting after the death of their Secretary, Mr. Perry F. Nursey, desire to place on record their appreciation of the invaluable services rendered by him to the Society during his long and honourable life, and to express to his widow and to his family their deep sympathy with them in their bereavement."

Mr. Sidney J. Ball: Mr. President, having known dear old Mr. Nursey for many, many years, and known him intimately, if I am permitted, I shall have very great pleasure in seconding the proposal. You have not said a word too much, and I thank you indeed for the kind expressions which you have made with regard to my dear old friend, for you, Sir, I know, believe that he deserved it, and we all feel that he did.

The Chairman: Well, gentlemen, then I will put it to you that the foregoing proposition be embodied in a letter, and sent by our Secretary.

The proposal was unanimously adopted by the meeting.

The Chairman: Then, I may say further, gentlemen, that we consider that it would be well that Mr. Nursey's memory should be preserved in connection with the Society of Engineers. We feel that it would be an easy thing to raise a fund sufficiently large for us to provide from its interest a premium that should be awarded, every year, or every other year, as the case may be, to be called "The Nursey Premium," which every recipient would value all the more from the name that it bore. The Council have this matter under consideration, and in due course you may expect to receive a notice to that effect. I feel sure that this will be widely supported, not only by those of his old friends who valued him personally, but by those members of the Society who have benefited so much by his wise conduct from time to time in his various capacities.

I wish, gentlemen, that were all. But, about the time that Mr. Nursey died, our Vice-President, Mr. W. H. Holttum, was taken ill, and within a few weeks he also passed away. Such an event should not pass by without notice, for Mr. Holttum was a Vice-President whom we all sincerely respected. The Members of the Council felt a very affectionate regard for him, and were always pleased to see him at our meetings, which he attended most regularly. We looked forward—with pleasurable anticipation—to the time, near at hand, when he would be our President, but he has been taken from us; and a letter has been written by the Council to his family to express our regret. I bring this before you now, so that we may feel we have placed on permanent record how much we appreciate what he has done for us. We have lost a valuable member of the Society, and the Council have lost a highly esteemed colleague, and I am sure that had he followed on to the presidential chair, it would have been well and worthily filled by one who was not only a good man in the best sense of the word, but also a good engineer.

I will only add that in Mr. Nursey's place the Council have elected Mr. A. S. E. Ackermann. We feel sure that he will make an excellent secretary and a worthy follower of Mr. Nursey. He is anxious to become acquainted with all the members of the Society as soon as possible, and I am confident that you will extend to him the courtesy and support that you always gave to Mr. Nursey.

LIQUID FUEL FOR INTERNAL COMBUSTION ENGINES.*

By R. W. A. Brewer, A.M.Inst.C.E., A M.I.M.E.,
M. Inst. Automobile Engineers.

The Aspect of the Fuel Question

The use of the term "liquid fuel" in this paper implies that the fuel is supplied to the engine in a "liquid" as distinct from a "gaseous" state.

It does not necessarily follow that the fuel enters the engine cylinder in a liquid state.

Since the gas engine was a commercial machine, the advantages of the use of a liquid fuel for driving this type of engine became apparent, and at the present time these advantages have become so enormous that there is quite a likelihood of the liquid fuel internal combustion engine superseding a large proportion of the steam units now in use. Manufacturers are designing and building these engines in constantly increasing sizes, and it is, perhaps, still a debatable point whether large marine engines of this type can be successfully used or not In a recent discussion at the Institution of Civil Engineers (see Proceedings, Vol. 168, p. 147), the author of this paper strongly advocated the adoption of a liquid fuel of high flash point for marine work, in place of producer gas, as proposed in that paper. He stated that the most important point in the problem was the production of the explosive mixture, and that he could see only one solution to the question, which was the adoption of a heavy oil—viz. the residuals after the lighter fractions had been distilled off. This heavy oil should have a flashpoint not below 350° Fah., and would thus not be dangerous when used on board ship. Every other system, such as a battery of gas producers, must necessarily be attended with great risk, and, in addition, the weight of such producers would be avoided when liquid fuel was utilised.

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* The President's Gold Medal was awarded to the author for this paper.

Then there are in the case of a liquid fuel the usual advantages of ease of handling, storage and manipulation, which are found when such a fuel is burnt in a boiler furnace in place of coal. The chief disadvantage of this system is one which applies to practically the whole of the oil question, viz. the control of the market. During the discussion before alluded to, Sir William White agreed with the author of this paper, when, speaking from his personal knowledge he stated, that there was the greatest difficulty in obtaining a binding contract for the purchase of oil residuals for fuel. High authorities had stated that there was no difficulty in guaranteeing almost unlimited supplies at a moderate figure, but they would not commit themselves in the form of a contract.

From the foregoing remarks the following facts are evident:—

Liquid fuels must not be considered solely as the products of petroleum, because the control of that market is in the hands of a very few large companies.

It is necessary to have one or more alternative fuels, in order that purchases of fuel can be made in an open market. It is, therefore, essential that engines designed for liquid fuel should be capable of being run on these alternative fuels without material alterations in their gear.

The manufacture of a national fuel, as distinct from an import from foreign countries, should receive every encouragement, as such a fuel could not be a monoply, and it is reasonable to expect that its price would be maintained at a steady and low figure.

We have recently seen how a great and concerted effort to encourage the use of alternative fuels has had the effect of reducing the price of a petroleum product, which points to the fact that at the present time the prices demanded by the large oil companies are false ones.

ATTEMPTS TO UTILISE THE HEAVIER OIL.

In order to successfully utilise a liquid in the form of oil in the cylinder of an internal combustion engine, two distinct methods have been tried to cope with the difficulties present. The fuel can be introduced :—

1. As oil, *without* chemical change, either in an atomised or partly vaporised and partly atomised form.
2. *With* chemical change, such that the oil before entering the cylinder has been wholly or partially decomposed into the lighter hydro-carbons.

In case (1) may be classed the first commercially successful engine, the Priestman, although in its effect it borders on case (2). The paraffin was injected by means of a nozzle into a chamber on the cylinder head and in direct communication with the cylinder itself. This chamber keeps hot, due to the heat of explosion under normal working conditions. The action of the spray being to atomise the liquid fuel, the heat of the chamber and the rapidity of compression convert the spray into a smoky vapour, which burns when mixed with its correct proportion of air. In this type of engine the compression is comparatively small, as a large compression would render the mixture unstable and liable to pre-ignition.

Distinct from this type is the Diesel engine, which works by compressing the air alone up to about 700 lb. per sq. inch. Into this highly compressed air at the end of the inward stroke of the piston, is injected the correct proportion of liquid fuel, by means of air at a higher pressure operating a jet. As this fuel enters the cylinder it burns spontaneously, without a sudden rise of temperature, throughout a greater part of the working stroke.

Finally, there is the Roots type of engine, which has the low or ordinary compression of about 70 lb. per square inch, in which each charge of oil is accurately measured, and injected into the engine cylinder during the suction stroke, and in which chiefly atomisation is relied upon to produce proper carburation of the air in the cylinder.

Under Type 2 come all engines having externally heated vaporisers, in which the liquid fuel is first converted, by partial decomposition, into a gaseous or semi-gaseous state before its introduction into the engine cylinder. A chemical change takes place in this vaporiser, and there is always the likelihood of deposits of carbon or heavy residuals forming here. Any possible variation in temperature between the vaporiser and the induction pipe will cause the vapour to condense in the pipe or round the inlet valve before it reaches the engine.

The effect of such an action may not be very marked in a stationary slow-speed engine running at constant load and speed, but when these conditions vary, the whole system may easily become deranged, owing to the small explosive range of a mixture of air and oil vapour ; so that when an oil engine is designed for varying loads and speeds, such as for motor car work, the following points are to be considered.

The oil-feed must be accurately measured, and in exact proportion to the air admitted at all times—any system of governing by throttling the air inlet 'must act upon the feed of oil in the same proportion.

A spray carburetter cannot give satisfaction when oil is utilised, as the action of a jet is not proportional, and there must of necessity be a great variation of the feed in such a device. This variation will occur not only for those working strokes in which the volume of air is reduced by throttling, but also when the throttle is full open and the supply of air unrestrained.

Owing to the small explosive range in the case of oil, either more or less vapour than that required to produce the best results will cause a miss-fire, which will be followed by one or more others, resulting in the stoppage of the engine. Usually about 20 per cent. of the total cylinder volume contains inert or burnt gas at the end of a charging stroke when the engine is firing correctly. But when an explosion is missed, the next charge is richer (perhaps too rich to fire), owing to the absence of this 20 per cent. of inert gas. An absolutely positive, accurately measured and mechanically controlled feed of oil is therefore a necessity in this type of engine, and this feed must be delivered every working stroke. The volume of oil required to carburate free air is so very small (about 2·5 per cent. by volume) that the chief difficulty is encountered in producing an apparatus sufficiently sensitive and at the same time one that will stand the wear and tear to which such an apparatus is subject.

THE USE AND MANIPULATION OF THE LIGHTER DISTILLATES OF PETROLEUM.

It is about ten years since the lighter fractions distilled from petroleum came into commercial use as a fuel in this country.

The same high-speed engine, such as is the prime mover in the majority of motor cars of the present day, was at that time in a state of infancy, and liable to frequent breakdowns through small derangements.

It was a necessity that the fuel for such an engine should be of the simplest nature, as far as its manipulation and properties for carburation were concerned.

Distillers of these lighter fractions know well that the majority of failures and breakdowns in the early days of the motor car were attributed to the imaginary, or real, bad qualities of the fuel.

This light fuel had originally a specific gravity of 0·680, and was very volatile, as the type of carburetter then employed depended solely upon the volatility of the spirit to effect its purpose. The spirit of 0·680 sp. gr. here referred to might be considered to be hexane, as it was a mixture of this compound with the higher and lower members of the saturated hydrocarbons, and was represented by the formula C_6H_{14}.

The earliest types of carburetter for this spirit consisted of a small tank containing the fuel, the necessary air being drawn over the surface of the fuel and thus becoming carburated. Later forms were fitted with wicks dipping into the fuel in order to avoid splashing and erratic behaviour of the liquid. This wick type of carburetter exists at the present day in a modified form, but it is obvious that as volatility is alone depended upon to effect the carburation, only the lighter fractions can be used.

The jet-spray types of carburetters now generally in use are semi-mechanical in their action, and when dealing with petrol of a specific gravity of 0·720 can be made to give a certain amount of satisfaction, at any rate to control the proportions of petrol vapour to air within the limits of ignition throughout a large range of demand. This spirit is usually employed at the present time, and the ratio of carbon to hydrogen is nearly represented by C_7H_{16} (heptane).

Spirit of Greater Density.

The specific gravity of the spirit alone is no true measure of its suitability for use in an ordinary jet-spray carburetter, but it is the range of boiling points, as observed in a distillation test, which determines the true value of any particular spirit.

The Fuels Committee of the Motor Union points out in its Report how spirit of a high specific gravity has been excluded in the past from our markets by an erroneous standard, but the thermal value per unit weight of Borneo spirit is higher than that of the spirit now generally in use, and it contains slightly more carbon in its composition. The author has found as a result of numerous experiments with this fuel an increase of 10 per cent. in its effect in a motor-car engine as compared with American spirit of 0·715 sp. gr.

This spirit must not be confused with a paraffin, as it evaporates completely at ordinary temperature without leaving any oily residue.

Pennsylvanian spirit has a composition of 84 per cent. C, 16 per cent. H, with boiling points between 60° and 150° C.

Paraffin consists of 85 per cent. C, 15 per cent. H, has

TABLE COMPARING DISTILLATION POINTS OF VARIOUS SPIRITS AND BURNING OILS.

Percentage coming over at the various temperatures shown		Varieties Distilled							
		Pratt's Sp. G., ·700	Shell, ·717	Shell, ·704	Shell "Borneo" spirit, ·753	Tar Benzol, ·878	Refined Peruvian Spirit, ·729	Rocklight Paraffin, ·825	White Rose Paraffin, ·800
		Deg. Cent.	Deg. Cent.	Deg. Cent.	Deg. Cent.	Deg. Cent.	Deg. Cent.	Deg. Cent.	Deg. Cent.
First drop	@	43	50	49	43	50	50	100	76
5 per cent.	@	50	62	55·5	59	51·7	57	142	142
10 ,,	@	53	67	60·5	70	53	60	152	149
15 ,,	@	55	71	64·9	74	54	65·5	160	159
20 ,,	@	63	74	66·6	76	56	70·5	163	167
25 ,,	@	71	78	70	77	59	75	170	175
30 ,,	@	73	79·5	72·2	78	72	76	176	181
35 ,,	@	75	82·5	75	79·7	75	78·5	180	188·5
40 ,,	@	77	85	77	85	79	82	189	191
45 ,,	@	80	87	80	91	80·4	83	195	196
50 ,,	@	80	90	84	95	82	84	200	200
55 ,,	@	81	92·5	87·2	94	82·7	85·5	210	207
60 ,,	@	90	95	90·5	97	83	86·5	217	205
65 ,,	@	100	97	94·4	98·1	84·5	87·5	223	210
70 ,,	@	103	101	97·7	100	85	89·5	232	219
75 ,,	@	108	104	103·3	102	86·7	92	238	228
80 ,,	@	110	108	108·8	106	88	94	247	233
85 ,,	@	130	112·7	115·5	110	89·1	96	260	242
90 ,,	@	133	121·5	121·1	117	90	99	270	252
95 ,,	@	134	140	140	132	93·8	102	296	258
100 ,,	@	140	154	152	141	97	107	300	262

boiling points between 150° and 300° C., and has a flash point not below 23° C.

Borneo spirit of a sp. gr. 0·760 consists of 91 per cent. C and 9 per cent. H, and distils completely between 60° and 150° C.

It will be seen from the table that even a heavier spirit up to 0·780 sp. gr., though its range of boiling points be increased in an upward direction, contains a proportion of lighter fractions which carburate air without the application of heat. In its action, therefore, it is distinct from paraffin, as the engine can be started cold, and the greater ratio of the explosive mixture makes it possible to run the engine until the parts become sufficiently warm to effectually carburate the heavier fractions present in such a fuel.

Referring again to the properties that are required in a motor car fuel, the distillation figures given in the table (page 163) have been obtained by Messrs. A. Duckham and Co., Ltd., and from these it is obvious that the Borneo spirit of 0·760 sp. gr. is very similar in its volatility to the better known light American (Pratt's) spirit, the only real difference being in the greater percentage of carbon present in the former. This higher percentage of carbon is due to the presence of benzol.

The author's experiments in connection with petrols of high specific gravities have been confirmed by later tests made by others interested in the development of the internal combustion engine.

The object of the trials was the observation of the relative behaviour of the different fuels under road running conditions, and tests were made over long distances varying from 1000 to 2000 miles, and also over shorter distances upon level roads—taking units of 1 pint, or 1 gallon of fuel, in each case, and noting the distance covered by the car upon such a fuel allowance.

The chief features noticed were:—

(*a*) Consumption in gallons per hour = C.
(*b*) Miles travelled per gallon = E.
(*c*) Speed of car in miles per hour = V.
(*d*) Approximate weight of car and passengers.
(*e*) Condition of road.
(*f*) Behaviour upon the level.
(*g*) Hill climbing.

Naturally, in tests of this nature, the conditions varied enormously, and a general average had to be struck, and the results deduced from an empirical formula constructed by the author for the purpose.

A variable Y, with a standard equal to unity, has been introduced for the purpose of taking into account the observed conditions of the road surface and load, before placing the various fuels in their relative positions in the table.

In the construction of the formula the author assumed that the useful effect of each fuel was proportional to E, the miles travelled per gallon; also to V^2 the velocity of the car in miles per hour, and inversely proportional to the rate of consumption = C.

As the speed did not vary to any marked degree, any error due to the assumption of V^2 is slight, but the results agree very well with those of the general observation upon the road.

V^2 was taken, as the author has found by experiment that above a certain speed the power required to propel similar cars against the air and other resistances varies approximately as the square of the velocity. For instance, it required 10 h.p. to propel a certain car at 30 miles per hour, whilst a similar car required 20 h.p. to propel it at 40 miles per hour. The road and axle resistance given by Col. Crompton for certain cars being constant at about 49 lb. weight, whilst the total air resistance was about 77 lb., when it was reduced to a minimum at 39 miles per hour.

Tests of Liquid Fuels. Petroleum Products. Long Tests.

	(1) Sp. Gr.	(2) $\frac{E\,V^2}{C \times 1000}$	(3) Y	(4) Col. (2) × Col. (3)
Borneo	0·760	11·6	1·1	12·4
Pratt's 0·715	0·755	10·0	1·0	10·0
Paraffin 0·810				
Borneo 0·760	0·770	7·4	1·3	9·6
„ 0·780				
Pratt's	0·715	9·5	1·0	9·5
Borneo	0·780	6·85	1·2	8·9

Vaporisation and Explosive Mixtures.

Refined petroleum is a complex mixture of hydrocarbons of various boiling points. In evaporation at temperatures below the boiling point such particles as escape from the surface of the liquid exist as vapour. In the case of any of the ordinary petrols, either of the light or heavy variety, evaporation continues at ordinary temperatures until the whole has disappeared without leaving an oily residue.

The proportion of hydrocarbon vapour which the air takes up varies with the volatility of the petrol and the humidity, pressure, and temperature of the atmosphere. For instance, dry air will take up the following quantities of vapour from petrol having a sp. gr. = 0·650.

17·5 per cent. by volume at 50° F.
27 " " 68° F.

before the air is saturated. These percentages are equivalent to

1 vol. vapour to 5·7 of air at 50° F.
1 " " 3·7 " 68° F.

showing that a small increase in the temperature largely increases the percentage of petrol vapour, which can be retained by the air.

Petrol of a sp. gr. 0·700 containing 83·72 per cent. C and 16·28 per cent. H has a vapour density of 0·24 lb. per cubic foot at atmospheric pressure when at a temperature of 32° F., or nearly three times the density of air.

With regard to the open evaporation of petrols of various densities and chemical compositions, the author has made a number of experiments in order to determine the effect of temperature and air currents upon the time taken to effect complete evaporation.

The apparatus consisted of an electrically-driven fan with speed controller, anemometer, a portable furnace, and a thermometer. Air currents of different velocities were passed over thin strips of paper saturated with the different fuels, and the time noted when the liquids had completely disappeared.

The experiments were made before the tables of distillation had been studied in order that no possible bias could be introduced during the experiments.

The results are given in the following table, and clearly show that although at ordinary temperatures there is a marked difference in the time taken by the petrols of the highest and lowest specific gravity, the application of heat makes the behaviour more nearly alike than does the effect of air currents alone. It also shows that although the chemical compositions of the Borneo spirit of 0·760 sp. gr. and the spirit of 0·720 sp. gr. are dissimilar, yet owing to the similarity of the distillation tests of the two, the time taken for evaporation in this way is practically the same.

The deductions made from such tests lead one to expect that when comparing the Shell spirit of 0·720 sp. gr., and the Borneo spirit of 0·760 sp. gr., no perceptible difference will be experienced when starting an engine cold, and that the behaviour of the engine in traffic, as far as flexibility is concerned, will be the same with either fuel. But when comparing the spirit of 0·780 sp. gr. (which contains fractions having a higher boiling point) and the other two spirits, we find that the former

EVAPORATION TESTS.

Velocity of Air, in Feet per Minute.	Temperature of Air in Degrees F.	Specific Gravity of Petrol, Shell, and Borneo.	Mean time of Evaporation in Seconds.
Still	58	0·720	30
		0·760	35
		0·780	90
300	59	0·720	22
		0·760	26
		0·780	40
240	95	0·720	15
		0·760	17
		0·780	27
350	100	0·720	14
		0·760	16
		0·780	25
350	160	0·720	9
		0·760	9
		0·780	17
560	95	0·720	12
		0·760	12
		0·780	18

requires assistance in the form of heat to accelerate the action of vaporisation. This heat can be added in the following ways. Either the carburetter itself or the incoming air can be heated by the exhaust, when the ordinary types of carburetter are employed; or, the spray of petrol can be mechanically broken up in order that such fractions as do not readily vaporise may be carried in suspension into the engine cylinder itself. If no precipitation takes place in the induction pipe, the whole of these heavier particles at once vaporise during the compression stroke. When a carburetter of the suction-spray type is employed, this atomisation can only be perfectly carried out, when the engine is kept running above a speed high enough to produce sufficient suction at the jet. It may, however, be expected that a good mechanical carburetter would deal more satisfactorily with a heavier petrol than the 0·730 sp. gr. here specified.

In order to form an explosive mixture with a fuel of this nature, knowing its chemical composition, it becomes a simple matter to ascertain the correct quantity of air required to effect complete combustion. The proportions must be such that the propagation of the flame is sufficiently rapid to produce an explosion.

Taking a Borneo spirit of 91 per cent. carbon and 9 per cent. hydrogen, 1 lb. carbon requires 11·6 lb. of air for its complete combustion—

$$\therefore\ 0{\cdot}91 \times 11{\cdot}6 = 10{\cdot}5 \text{ lb. of air for the C.}$$

1 lb. hydrogen requires 34·8 lb. for its complete combustion—

$$\therefore\ 0{\cdot}09 \times 34{\cdot}8 = 3{\cdot}14 \text{ lb. of air for the H.}$$

Hence, theoretically, the total air required = 13·64 lb., which at 62° F. = 182 cubic feet at atmospheric pressure. In practice, we find the excess of air admitted greatly dilutes this mixture, and that instead of a mixture containing 1·8 per cent. of petrol vapour, the vapour is diluted with 60 or 70 times its own volume of air, i.e. the percentage of petrol is only 1·6 or 1·43.

The investigations of Sir B. Redwood upon the limits of explosion of mixtures of petrol vapour and air show that when using a petrol of 0·720 sp. gr., and firing the mixture in a closed vessel by means of a naked flame, the most explosive mixture consisted of 1·86 per cent. of petrol vapour. With a petrol of 0·680 sp. gr. these figures become 2·5 per cent., as is shown in the following table:—

Specific Gravity of Petrol 0·680, giving 190 to 260 times its own Volume of Saturated Vapour.

No ignition with	1·075	per cent. by volume of petrol vapour.
Silent burning with ..	1·345	,, ,, ,,
Sharp explosion with ..	2·017	,, ,, ,,
Violent explosion with ..	2·352	,, ,, ,,
Less violent explosion with	3·362	,, ,, ,,
Burning and roaring ..	4·034	,, ,, ,,
Burning silently	5·379	,, ,, ,,

The most violent explosion occurred when 12·25 volumes of liquid were mixed with 100,000 vols. of air.

These experiments were conducted without a previous compression of the mixture, and it is chiefly owing to this compression in an engine cylinder that such weak mixtures as are used in modern practice can be made to explode.

The author has made many tests on the road with a view to ascertaining the minimum strengths of explosive mixtures used in his motor car, the engine of which has four cylinders, each 90 mm. diameter by 110 mm. stroke, and observations were made as to the rate of consumption, etc.

Petrol consumption, one gallon per 20·5 miles. One gallon was consumed during 38,700 engine revolutions = 77,400 cylinder charges of mixture.

Each cylinder volume swept by piston = 698·5 c.c.

One gallon of petrol = 4543 c.c.

Taking a carburetter loss of 15 per cent., petrol used = 3860 c.c. net.

Total volume of mixture at 14 lb. per square inch absolute, and 110° F. = 77,400 × 698·5 = 54 million c.c. = 46·7 million c.c. at 15 lb. per sq. in. and 62° F. That is 8·25 vols. liquid petrol per 100,000 vols. of mixture.

This figure is for Borneo spirit of 0·760 sp. gr. The figures given by authorities on the subject for the best proportions are with 0·680 sp. gr., 12·25 vols. liquid to 100,000 vols. air theoretically and without compression.

The test figures show for Borneo 0·760 : 59 vols. of air to 1 vol. of vapour = 1·7 per cent. of petrol vapour, as against 40·0 vols. air to 1 vol. vapour = 2·5 theoretically for the 0·680 spirit: and for 0·722 sp. gr. spirit = 1·86 per cent. theoretically.

From the above figures it is evident that the proportion of petrol to air is high, and that either more air could have been used or the assumed loss of 15 per cent. in carburation is too low.

The Sources of Supply and the Question of Price.

As far as we in this country are concerned at the present time, the United States of America can be almost ignored as a source of supply for the petroleum fuels. Originally practically all the lighter distillates of petroleum imported into this country were obtained from the Pennsylvanian fields, as there was only a small percentage of petrol in the Russian oil, our other source of petroleum at that time.

Now the home consumption of American spirit has reached such proportions, together with the depletion of the wells in that country, that the amount available for export is very small. Whereas in 1905 we imported 10½ million gallons of petroleum spirit from America out of a total of 18½ million gallons, this importation had fallen to 2½ million gallons for the first six months of 1907, a decrease to less than 20 per cent. of the total amount imported.

The great increase in the demand for petroleum spirit in this country is shown by the following figures supplied by Mr. Alexander Duckham:—

Year 1904	11,972,000 imperial gallons.
„ 1905	18,658,000 „
„ 1906	26,792,000 „

and the percentages of imports from the different sources have been as follows:—

Country	1904	1905	1906
	Per cent.	Per cent.	Per cent.
United States	50	56	29·8
East Indian group	37	42	61·4
Roumania	8·2	0	8·6
Other countries	4·8	2	0·2
	100	100	100

These figures show the change in the sources of supply during the last few years, which change is still more marked for 1907.

Russian oil contains practically none of the lighter fractions which have been used in the past for motor spirit. Also the labour disturbances in Russia account for its absence from the above list.

Roumania, on the other hand, does a large export trade in spirit, the bulk of which goes to France and Germany.

ROUMANIAN SPIRIT OBTAINED, IN GALLONS.

	Gallons
1903	14,500,000
1904	18,600,000
1905	23,500,000

The bulk of the spirit now coming into this country is from the fields of Sumatra, Borneo, and the East Indies, and it is only within the last few years that the companies operating these fields have exported their light products to Europe. The oil from these fields contains a large percentage, up to 20 per cent., of a spirit distilling between 60° C. and 150° C., and referred to previously as Borneo spirit, and also a considerable quantity of the more familiar Shell spirit, having a sp. gr. of 0 715 to 0·720. The amount of spirit available from these fields depends upon the market for kerosene and other residuals. Sir Marcus Samuel in a recent speech stated that although they could produce an enormous quantity of spirit, "the price would depend upon whether they could find remunerative markets for the other products left when the petrol was removed from the crude."

As these products constitute something like 90 per cent. of the total there is very little assurance that the petrol market will continue in a stable condition for any length of time. The price obtained for the residuals is primarily governed by the price of coal; for instance, Russia at the present time utilises the bulk of its production locally as fuel oil. It would not pay to distil this oil for the sake of a small percentage of petrol.

The removal of the specific gravity standard might make the necessary difference, as far as Russia is concerned, whether it would pay to distil or not.

Considering the East Indian oil, in addition to the demand for fuel oil, which is very small, the chief marketable residual is kerosene. The companies, however, find this market decreasing year by year.

As compared with other fuels petroleum products show unaccountable fluctuations. This is undoubtedly due to the fact that the control of supplies is in very few hands. It is, therefore, an easy matter to create artificial prices, which must be paid by the consumer. Users of liquid fuels of the heavier types know how difficult it becomes to enter into any sort of contract for supplies, and that when sums of money have been expended in fixing apparatus for burning heavy liquid fuels, the price of such a fuel is raised until no economy results in return for the change.

As regards the lighter fractions, some idea of the fluctuation in price can be gathered from the following list of prices to agents in London, for spirit delivered in cans and cases :—

	Per Gallon
November 1904	7*d.*
November 20, 1905	8*d.*
January 19, 1906	9*d.*
February 21, 1906	9½*d.*
May 3, 1906	10*d.*
August 2, 1906	12*d.*
December 24, 1906	13*d.*
July 26, 1907	12*d.*

The final reduction of one penny occurred simultaneously with the issue of the report of the Fuels Committee of the Motor Union.

This serious rise in price has proved almost disastrous to users of commercial and public vehicles, particularly motor omnibuses, in connection with which the margin of profit is so small. The larger companies have contracted for supplies at a low figure, but the early contracts are now expiring. All the later contracts have been made at higher figures, and whilst the earnings remain the same the profits must decrease.

This all points to the necessity of healthy competition in the fuel market, and several alternative fuels have been suggested for use in a high speed internal combustion engine.

Benzol.

When we look for a substitute for petrol, a home produced fuel, which can be utilised without in any way altering the existing arrangements of the engine or carburetter, undoubtedly holds out great hopes. Such a fuel, known as benzol, is a distillate of coal tar, or can be extracted from coal gas. It is a light hydro-carbon, C_6H_6, and is a clear liquid similar in appearance to petrol, but having a slight smell of sulphur, due to the presence of about 150 grains of sulphur compounds per gallon. The specific gravity of pure benzol is 0·885, boiling point 80° C. or 176° F.

Total evaporation point of crude benzol 145° C. or 293° F., and 1 gallon contains 163,680 British thermal units of heat, as against 157,142 B.T.U. for petrol, and has an explosive range from 2·7 to 6·3 per cent.

The largest source of supply is from coke ovens or gas works.

In the modern systems of coke manufacture for iron smelting the by-products obtained in the distillation of coal are collected instead of being allowed to go to waste, as in the old style of beehive oven. The benzol obtained in the gases from distillation is readily absorbed by means of suitable oils, from which it is afterwards extracted by distillation.

Commercial "90 per cent. benzol" is a spirit of which 90 per cent. evaporates in a retort at a temperature of 120° C,. and the production of which amounts to about 5,000,000 gallons per annum in this country. This supply could be largely increased by the installation of suitable recovery plant, should the demand warrant this expenditure. The supply could thus be doubled within a very short time. The present price of this fuel when refined is about 9*d.* to 10*d.* per gallon at the makers' works, the process of refining and washing costing about 1*d.* to 2*d.* a gallon. The process of washing by means of sulphuric acid and soda partially eliminates the sulphur compounds, but unwashed benzol might be made suitable for motor car work by distilling out the lighter portions, and with them the bulk of the impurities.

With regard to the use of 90 per cent. benzol as a motor fuel the author has made a number of experiments, the results of some of which are given below, and can be compared with those previously given for petrol of various densities.

LONG TEST.

	Miles per Gallon.	Distance.	$\frac{EV^2}{C \times 100}$	Y
Benzol, sp. gr. 0·875	27·2	116 miles	14·8	1
SHORT TESTS.				
,, ,,	24	14 miles	12·25	in traffic.
,, ,,	22	15 ,,	12·4	,,

The distances travelled per gallon compare very favourably with the best results obtained with petrol, viz.:—

0·715 sp. gr., 18 miles per gallon.
0·760 „ 21·5 „

The engine pulled well, and the speed of the car was kept about the same as when using petrol.

The author finds that on some occasions it is advisable to use rather a larger jet with benzol than with petrol, but care must be taken to admit sufficient air, or sooting takes place inside the cylinder. The smell of the liquid in the unburnt state is slightly more noticeable in the case of benzol, but the exhaust gases have little smell and no tendency to smoke.

ALCOHOL.

In spite of what has been said against alcohol as a motor fuel, it is the author's opinion that alcohol has great possibilities in this direction. A clear statement is given in the Report dated July, 1907, of the Fuels Committee of the Motor Union as to the requirements and behaviour of this fuel and to the high compression necessary to obtain the best results.

The author has obtained samples of commercial methylated alcohol having a sp. gr. of 0·833, and with them conducted a number of tests, using other ingredients in varying proportions. He has succeeded in running his motor car satisfactorily upon these mixtures and also with alcohol mixed with only 25 per cent. of another fuel.

The fact is here stated in order to refute many biased opinions which have been expressed of late as to the impracticability of alcohol as a fuel for this purpose. Sir Marcus Samuel, in the speech previously referred to, remarked with reference to alcohol: "Although alcohol might prove an excellent bogey with which to attempt to frighten the producers of petrol, they did not entertain the smallest misgiving that this spirit could ever become a competitor to their petrol, for the simple reason that it did not contain those qualities essential for the running of motor vehicles."

Considering now these essential qualities, the properties of alcohol may be briefly summarised as follows: ethyl alcohol C_2H_6O, a volatile colourless liquid with a specific gravity of 0·806 at 0° C. Calorific value about 12,600 B.T.U. per lb. Boiling point 78° C. Explosive range 4 to 13·6 per cent. with air.

Methylated spirit, consisting of 90 per cent. ethyl alcohol and 10 per cent. methyl alcohol (CH_4O), has a calorific value of about 11,000 B.T.U. per lb.

The following is an approximate comparison :—

	Petrol 0·722	Methylated spirit
Calorific value in B.T.U. per lb.	20,000 (gross)	11,000 (gross)
Net calorific value per lb., i.e. heat converted into work..	4248 B.T.U.	3322 B.T.U.
Thermal efficiency =	21 per cent.	30 per cent.
Heat converted into work = Calorific value	..	..

In practice, a petrol motor rarely exceeds a thermal efficiency of 18 per cent., whilst with an alcohol motor the highest efficiency is readily obtained, and, considering that a gallon of alcohol weighs about 12 per cent. more than that of the petrol, the net value per unit volume is about the same. A great advantage of alcohol is its uniformity of composition, the whole of the spirit distilling over at a temperature of about 78° C.

DISCUSSION.

The CHAIRMAN moved a vote of thanks to the author for the paper which he had just read. They would all agree that this question was one of very great importance at the present time. It would be observed that the author, being a member of the Automobile Club, had spoken rather in reference to road traction; but the question embraced a very much wider field, ranging from the beautiful airship, which some of them had been examining at the Crystal Palace that day, to the somewhat larger vessel which had started on its second voyage across to America, perhaps to lower the record. Anything which would tend to increase their acquaintance with the special qualities of liquid fuels was of very great importance. Mr. Brewer, as they knew, was an authority on the subject, and the Society was much obliged to him for bringing the question forward in the able and interesting way that he had done.

The vote of thanks was carried by acclamation.

Mr. ALEXANDER DUCKHAM said that he spoke as a motorist, and did not know very much about stationary engines. In the first place he would like to ask the author why he mentioned 350° F. as being the point which one should fix for oil for use on board vessels. It seemed to him that it could be made very much lower. If they were going to stipulate 350° F., they might go up to 700° F. or something of that sort to guard against extraordinary circumstances and still not be safe. They needed only to protect themselves against the ordinary local risks, such as the temperature of the atmosphere. If they were going to introduce an arbitrary standard of 350°, which was about the flash-point of spindle-oil or light lubricating oil, they would reduce the source of supply very considerably, and increase the difficulty of securing complete combustion.

There was another question upon which he would like to ask the author to give information. Supposing that one was using a fuel which distilled under 300° F., such as the ordinary petrol, and they used in its place another fuel which distilled at perhaps 500° F.; now if the fuel, the carburetter, and the induction pipe were heated to 200° higher than with the former fuel, would as good a result in the engine be obtained as with the lighter spirit running under ordinary conditions? Would the extra amount of heat have the desired effect? Under those circumstances there would be no chemical change of any kind, as the temperature would not be high enough to have such effects.

He was very glad to see that Mr. Brewer mentioned the bogey of specific gravity. The question of specific gravity in fuel questions, was almost as bad as in the lubricating question, where a man thought that he must have a high specific gravity in order to obtain a good viscosity. Of course, the two did not necessarily run together. It seemed to him that the distillation point was not of much importance, because, as the paper showed, the vaporisation was really the criterion. The vaporisation did not correspond with the boiling point. Take, on Mr. Brewer's table, the case of commercial alcohol, where the boiling point was, perhaps, from 75° to 85° C., and take the Borneo spirit, which boiled between 50° C. and 150° C., a very much larger range. In the case of the commercial alcohol, where they had a range of only 10°, starting at about 75°, the vaporisation, he should have thought, would have been far more rapid than in the case of the Borneo spirit, where there was a very big range, but the table showed that this was not so. He did not know whether experiments had been made, by which one could compare the distillation point with the vaporisation.

Mr. Brewer had introduced a rather disturbing figure at any rate for the motorist—he (the speaker) did not know how it affected other people—when he spoke of a carburetter loss of 15 per cent. That seemed to him to be very heavy, and he did not quite see where this loss came in, unless it was just a question of leakage in the carburetter. Unless there was a leakage it ought to go into the engine. He made an experiment some time ago which rather bore upon this point, and he would mention it later as a loss discovered in the exhaust. With reference to Russian spirit, they knew that in Russia there was very little spirit. It amounted, he believed, to somewhere about 1 per cent., and perhaps not that on an average. It must be remembered that the refiners had to get rid of the spirit, as they could not send any oil out into the market containing the spirit. They had therefore to distil in any case, and so he supposed that the spirit went into the petrol market, but the amount was so small that it really could not be considered as a source of supply. At the present moment it was only the high price of the spirit that encouraged the Borneo market. The freight from Borneo, he should think, must be well over 2*d.* per gallon, and that was a very big proportion to pay for freight. If the price of petrol dropped to the figure of some years ago, the Borneo market would hardly be able to compete in the supply.

He should like to ask Mr. Brewer whether he found that the high specific gravity of benzol made much difference in the feed from the carburetter. It had struck him that the specific gravity of benzol being about 0·880, and the specific gravity of the petrol being perhaps about 0·720, the level of the float in the float-chamber was very different, that is roughly 20 per cent. lower. It must require increased suction to raise the spirit from the jet, and of course, this would automatically reduce the supply of the richer fuel. Again, with regard to benzol, he would like to ask whether Mr. Brewer ever found that the benzol being so very high in calorific value, owing to the presence of a large percentage of carbon, gave any trouble with high compression. On one of his cars he had had a lot of trouble in that respect, not only with benzol, but with "Borneo" spirit. Borneo spirit contained a large amount of benzol; he thought about 25 per cent. He found on one of his cars that with very high compression on "Borneo," he at once pre-ignited, and he could not run.

Some time ago he made some experiments. He ran an ordinary Pratt spirit, which distilled between 50° and 160° C., and he found that from his exhaust, putting the condenser on to his silencer, he collected spirit. It had gone right through the engine, only the heavier portions of the spirit however so doing. As it was only these heavier fractions which he condensed, he came to the conclusion that the lighter fractions had been vaporised and used, whereas, perhaps, the heavier fraction had gone through as an atomised liquid, and that the lighter fractions as vapour had been preferentially selected for combustion. Instead of using spirit boiling at from 50° to 150° C., he took only that fraction boiling at from 50° to 100° C. Previously he had been getting about 22 miles to a gallon, but with the lower-boiling spirit he got from 38 to 39 miles to the gallon, and could condense absolutely no spirit at the exhaust.

Mr. W. H. BOOTH said that, when he first took an interest in liquid fuel, he came to the conclusion that liquid fuel could never become a commercial success on a generally large scale, and that it could be used only for special purposes, that is to say, under the conditions prevailing at that time. He was not aware that the conditions were very different to-day. The amount of liquid fuel at the time he mentioned was only about 5 per cent. of the total fuel production of the world, and so people who at that time were advocating the universal use of liquid fuel, had evidently not taken into consideration, the fact that the proportion was so very small that liquid fuel could never become universal. It could be used only for special purposes, such as in motor cars or for naval purposes. There was a source of supply, as the author had pointed out, from the distillation of coal. A great deal had been heard recently about the new fuel coalite, which seemed to him to be simply a form of ordinary coke. There must be an enormous amount of by-products in the production of that material, and they ought, therefore, to procure a lot of liquid fuel suitable for motor car work or heavier engine work by properly utilising all the coal. In that way they would also prevent smoke, because they would use the coal for steam-raising purposes and would make no smoke. Petrol, at present, did not seem to him what might be called a commercial fuel. It was getting short in quantity, and its production generally was short. That, he thought, must be the reason why the price varied so much, rather than the greed of the producers. Anybody who held a material of which the supply was short, would, he thought, get the highest price that he could get for it. That showed that, if light liquid was to be used for motor cars in the future, the supply must be obtained from some other source in the shape of benzol. There was also the fact that petrol was not a homogeneous liquid. It was a mixture of several liquids of different specific gravities. Some time ago he was trying to get a public institution lighted by some people who had made a very great profession of what they could do with petrolised air. They did not make a success of it, and he pointed out to them that the mistake which they were making was that they were endeavouring to petrolise the air by taking the air to the petrol, instead of taking the petrol to the air. That made a great deal of difference. If the air was taken to the petrol, the air selected the lighter portions and left the heavier portions behind. He found that, when they were getting results, they were running away all the heavy portions which were left behind, so that the consumption of petrol was really enormous.

The other day at the Engineering Exhibition at Olympia, he saw another petrolised gas installation, and it seemed to be doing very well. He asked them how they made their mixture, and they told him that they carried the petrol into the air. They got a jet every few seconds, so that the whole of the jet was evaporated and the whole of the liquid was used. That seemed to him to be the proper way. It also pointed to the mechanical carburetter being the proper thing for motor vehicles, and other vehicles of the same sort. A jet of petrol must be taken and injected into the air The air could not be allowed simply to select for itself from the carburetter. Otherwise, as he could easily see, the carburetter waste of 15 per cent. referred to by the author might easily be obtained. He had often seen motorists opening a tap on their vehicles and running out what they called useless petrol into the road. It seemed to him to be stuff which was left behind by the improper form of carburetter employed. Generally for motor car work the time would come when heavy oils would be used. He meant crude oils. A few weeks ago, when he was in Toronto, his attention was called to a heavy oil engine, different from any engine he had ever seen. There was a compression of pure air, and the fuel was injected into the air just at the point when ignition was required. The cylinder was water-jacketed up to the working point of the piston, and then on the back of the piston was a considerable length, an additional length, in the form of a cast iron bell almost filling the cylinder. The back portion of the cylinder was not jacketed, but always remained hot. He watched the engine at work, in fact, several of them. There was a large number of engines under manufacture in the shop As far as he could learn, the Johnston engine had been altogether successful. He inquired as to whether there were any great failures of the hot portion at the back of the cylinder, and he was told not. The cylinder was always hot at the back. Any heavy drops of liquid falling upon the hot portions of the cylinder were vaporised, the result being that the whole of the fuel was consumed. The cylinder was kept hot in the combustion space instead of being chilled by jackets, and there was no difficulty with the work of the piston, simply because the cylinder was extended, and the piston was extended also, and so the hot gases did not reach the jacketed portion in any way. Alcohol was a homogeneous fuel, and he did not see why alcohol should have any difficulties as regards use as a liquid fuel in a motor car. It should do pretty well. It was not entirely a hydro-carbon, and there was a considerable proportion of water in its composition, that is to say, oxygen which was more or less combined with hydrogen, so that its calorific capacity was reduced, and there was a tendency to form certain acids which gave trouble, but he was told that to a great extent the troubles had been overcome. He should like to ask Mr. Brewer something more about the carburetter loss of 15 per cent., and whether it was due to the cause he had endeavoured to indicate.

Mr. A. Beeby Thompson said he was afraid that he could not say very much about small internal combustion engines, because his experience had been with engines of low speed and much greater power. Being associated with oil fields all over the world, he naturally tried to utilise internal combustion engines as much as possible. He was afraid that purchasers gave makers in England a considerable amount of trouble, for they ordered an engine for one purpose and promptly used it for another. Perhaps they had a kerosine engine sent out, and, before they knew what was going on it was being used with "crude" oil. In the same way they sometimes had an oil engine which they tried to convert to gas. Really, they did a very great deal of experimenting in that way and they got some rather curious results at times. He thought that the internal combustion engine had a very great future before it. In Baku the cost of production of oil was rising enormously, and as fuel constituted the chief cost in raising the oil it was the item to be considered most. He believed that, although electrical power was being generated at a very cheap rate, and large gas fields were being opened within the vicinity of oil fields, Hornsby-Ackroyd oil engines were being largely introduced into the Baku oil fields. A number of years ago he remembered a single isolated well working with steam, which cost approximately 50*l.* monthly in fuel and water. The replacement of the steam engine by a Hornsby-Ackroyd oil engine led to a monthly saving of 40*l.*, the cost of running being one-fifth that of the steam engine. That showed the enormous saving which could be made by using internal combustion engines in special cases. In oil fields all over the world, where they were not under legal restrictions as they were in England, they naturally experimented much more than they would dare to do in this country.

One company with which he was professionally associated sent a tank-ship on a very long voyage with crude oil. He knew that the crude oil used contained quite a large percentage of fractions which had a boiling point certainly below 70°, but still the boat performed the voyage to the satisfaction of the engineers. Naturally there was a little danger, but, if the joints were all carefully made, the ventilation properly attended to, and great precautions adopted on board as is usual on a tank steamer, there is no reason why such crude oils should not be used. In the Navy the safest materials must be used, but on tank ships there is no serious reason why the lighter grade fuels should not be burnt. In South America a company supplied fuel oil for the railways. At one time the railways were supplied with residuum, but after a time when residual oil was scarce, crude was added to the residuum. At times the railways had taken crude oil entirely, and he believed they had never had an accident, and were quite satisfied with the results.

He believed that there was a very great future before the use of liquid fuel, although Mr. Booth seemed to think that its use would always be strictly limited, owing to the shortness of supply. He supposed that in time the best coal would become exhausted, or that, at any rate, it would become much more expensive, thus leading to a demand for a high-class substitute. Whilst the Pennsylvania fields, and other eastern American fields were practically exhausted, or the production from them was so small that it scarcely paid unless they had a very high grade oil, there were large sources of supply in Trinidad, New Zealand, and in West Africa awaiting active development. He said that possibly those present had noticed recently in the press some misleading statements to the effect that the Government were erecting very large storages about the English coast for Nigerian oil. Still in Nigeria, they had a source of supply, and he thought that within ten years Nigeria would be producing large supplies of oil. Then in India, Assam and Burmah, there were large sources of supply too, and the fuels from there were bound to come forward during the next few years. In Russia, out of something like ten thousand square miles of known petroliferous ground, only six or eight square miles were being worked—certainly not more than ten square miles were being worked, and yet those ten square miles had in the past supplied half the world's production. It was unlikely that those small areas should be the only such rich pieces of oil-bearing ground to be found in the world. It was probable that there would be found something of the same sort in our own colonies, when certain active prospecting had further developed. The Dutch East Indies were supplying a very large percentage of the petrol coming into England. He had been told by people who had visited the Dutch East Indies that there were thousands of square miles of land there likely to produce oil. If that were the case there were enormous resources both of motor spirit and fuel oil to fall back upon. If only oil were more generally worked by a number of small companies, instead of by a few very large ones, there would be much better and cheaper sources of supply. Oil could not be distributed without enormous expenditure in installations and tank ships, and that fact kept out usually the small producer, who naturally must sell his oil to the big people for them to market.

He had recently had brought to his notice a new boiler in which liquid fuel was consumed in the water itself. There were no tubes or combustion chambers, but by means of compressed air at a little higher pressure than the boiler, oil was injected into the boiler and completely burnt in the presence of water. By that means very great economy was obtained, owing to the immediate absorption of the heat generated and the intense circulation got up, and it was estimated that the boiler space occupied was about one-tenth of what an ordinary boiler of equal capacity would occupy. The amount of air which had to be used with the oil to produce complete combustion, naturally prevented ordinary condensing engines being used, because the quantity of air was so great that the air-pumps would have to be very large. Evaporation tests showed something like 18 lb. of water per lb. of oil. In such an invention, they had something which might revolutionise locomotives, for instance, where the limit of size had already been reached, but liquid fuel was essential.

Mr. McKinney said he thought that it would have been better if the author had gone further with the experiments recorded in the first table; that is to say, if he had tried different temperatures with a constant air velocity, and *vice versâ*. Where they had two variants occurring in alternate equations, one did not get so much information as one would like to have. Perhaps the author had carried out further experiments of which they did not see the result in the paper. With reference to the advantage of compression in the cylinder of an internal combustion motor, he asked whether there was any advantage from using a weaker mixture than is usual with a compression of six or even more atmospheres.

He (the speaker) found that it was difficult to cure the preignition of the charge. owing to the heat generated by the high compression. Possibly it was owing to the inaccurate kind of atomising apparatus in the carburetter with which he experimented. The author, in referring to alcohol, said it would give the highest efficiency. He presumed that he meant this as a sort of comparative relationship to petrol. He thought that it was admitted that alcohol did not give much more than 20 per cent. or perhaps 25 per cent. Mr. Booth, when speaking of alcohol, said that there was no disadvantage, as far as he knew, in regard to using alcohol. He (the speaker) thought that there was one practical disadvantage, in the difficulty a private user would find in maintaining it in a pure state, because it had such an extraordinary affinity for water. If a man like the ordinary user of a motor car took up alcohol as fuel, he would need to have this particular point brought to his notice, otherwise he would find that his engine would start on that fuel one day, while on another it would do nothing of the kind.

As to the point about the 15 per cent. leakage of the carburetter, perhaps Mr. Brewer, in speaking of that, referred to the influence of the movement of the inlet valve on the contents of the induction pipe. When experimenting with an engine of the single cylinder type, he found that the blow-back there, in connection with the vibration of the needle in the carburetter caused as great a loss at times as 40 per cent. of the fuel. This depends partly upon the nature of the engine, and partly upon the carburetting or atomising agent in use.

Mr. Veitch Wilson said he had hoped that perhaps he would be able to find in Mr. Brewer's lecture some arguments or facts which would enable him the better to deal with the question of lubrication in which he was more particularly interested. His friend, Mr. Duckham, would sympathise with him, and perhaps some of the representatives of other oil makers present would take the same view. Mr. Brewer very ingeniously avoided almost entirely what was a somewhat thorny question. He (the speaker), however, had been able to deduce from Mr. Brewer's remarks some incidental confirmation of a theory of his own, which was that the lubricating oil is not always responsible for all the deeds and misdeeds which are attributed to it. Mr. Brewer had told them that in his own experience he found deposits frequently formed from various fuels. That had been his (the speaker's) own idea. The difficulty had been to convince the users of the cars that those deposits came from the petrol, and not from the lubricating oil. When engaged in rebutting such charges against lubricating oil, he had occasionally derived some comfort from the thought that, perhaps, when the motorist complained of deposits in his motor, and attributed them to the lubricating oil, at the same time he wrote in similarly vigorous terms to the spirit merchant, and told him that the deposits in his cylinder were coming from the spirit. After the able manner in which the leading questions raised in the paper had been discussed by previous speakers, there was very little left to be said, but he would like to know from Mr. Brewer the particular sense in which he used the word "residual." Formerly, he (the speaker) was connected somewhat intimately with the Scotch oil trade, and in that particular trade they applied the word "residual" mainly to "still bottoms" and "acid tars." Ordinarily, in the oil trade, the word "residual" was applied to what was really the final residue left, an article of little or no commercial value. Those residuals were obtained from the bottoms of the still, and were more or less neutral. The still used to be run down occasionally to coke, which was used for burning or for making founder's blacking. Sometimes it was taken off at an earlier stage and used for asphalt for making up roads. The other residual, one which used to come in for liquid fuel thirty or forty years ago, was the acid tar. It was a very great nuisance to the oil refiners in Scotland. They kept burying it in pits till there were no pits left to bury it in. Then they erected brick furnaces in which the stuff was burnt. That made a black smoke rise all round the furnaces, and there was trouble with the farmers, and that was stopped. Then they began to experiment with a view to the use of the stuff as fuel in furnaces. One of the first men who applied it in connection with steamships was Mr. William Maclaren, the manager of a steamship line running out of Glasgow and an enthusiast in the matter. After a good deal of trouble, he adapted one of his ships to burn liquid fuel, but, when he had succeeded in adapting that vessel to burn liquid fuel, the price went up, and he found that he could not count upon a sufficient supply, because simultaneously with himself some firm on the East coast also fitted their vessels to burn liquid fuel, and the supply was insufficient to meet the demand. The next attempt to burn liquid fuel was introduced by Mr. Norman Henderson, the manager of the Broxburn oil works, who fitted a tank on the top of his boiler, heated it with steam, brought the tar down in a pipe to the front of the furnace and injected the liquefied fuel with a steam-jet on the top of a fire-brick plate heated by coal, and burnt the two together. That system of using liquefied fuel was adopted at many other works.

He had been rather put out by reference to the figure of 350° C.* flash point which Mr. Brewer had used in the paper, as he could not reconcile that figure with any residuals, as he called them. To him, that figure pointed to some of the intermediate distillates which, he thought, were more what Mr. Brewer referred to, namely, the distillates that occurred between the burning oil, having a maximum specific gravity of 0·820, and the lubricating oil having a minimum specific gravity of 0·875. Ultimately, after knocking about for some time, those settled themselves down into two grades, one of which was sold at about 0·865, mainly for cleaning machinery, and the other, which ran about 0·840, was well washed and largely sold, as a high flash-point burning oil. That was sold, if he remembered rightly, by Young's as a lighthouse oil. Mr. Duckham, who questioned the necessity for such a high flash-point, might not remember that fact, because in these present days of electric light, people did not think much of oil on board ship. In those earlier days, he believed, the Cunard and some other companies, and also the British lighthouses, used that oil with a flash-point of somewhere over 300° F. as their staple illuminant. He did not know that that figure was too high. They had been told by Mr. Thompson of some steamship with which he was acquainted in which the best precautions were taken, where crude oil was used with a flash-point of 70° F., but he was afraid that the owners of the Cunard steamships or of any other great steamships would not venture to put such a low flash-point oil on any of their ships.

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* 350° C. was given as a boiling-point.—R.W.A.B.

With regard to what the author said on page 159 that "liquid fuels must not be considered solely as the products of petroleum," he would refer to the products of shale. There was another source of supply of liquid fuel which had been overlooked, which was a pre-eminently British source, and which ought not to be neglected. That was in connection with the distillation of peat. There were vast beds of peat in Scotland and Ireland. Peat was largely used in the earlier days of paraffin oil as a source of paraffin oil. It gave off no particularly offensive smell from burning, although it was very nasty on the hands and still more on the clothes. Mr. P. Moir Crane many years ago told him that his first connection with the oil trade was with the distillates of peat in North Ireland. He (the speaker) remembered in the early days, in the halcyon days of the oil trade, that Sir James Matheson established a large peat industry in the island of Lewis, and so the fact remained that, if there was a market, peat would afford an almost inexhaustible source from which liquid fuels could be derived.

Another form of fuel was coal-dust, and they would all probably remember that, many years, in a Glasgow flour-mill, it was discovered that flour-dust was also a potent fuel, for it exploded and blew out the sides of the mill.

Mr. Brewer's remark that he had found trouble from deposits recalled a little conversation which he (the speaker) had with Mr. J. S. V. Bickford of Camborne the other day on the question of the action which takes place when the liquid fuels were used in an engine. Mr. Bickford told him that he had been a little sceptical as to whether oil in petrol engines was volatilised, and, from some experiments he had made by means of some glass apparatus which permitted him to watch the behaviour of the oil in its progress from the nipple to the engine cylinder, he found that the glass apparatus became coated with films of condensed oil, and he argued that what was invisible was also going forward in a similar atomised rather than gasified, condition. He (the speaker) remembered that a gentleman had told him that his oil was all wrong, and that the induction pipe before the induction valve had been coated with oil, and he sent the pipe to him to be examined. The statement that the thing was coated was certainly correct, but, when they began to scrape it, they found that the deposit could not have proceeded from the lubricating oil. It was a deposit upon the bend of the pipe above the induction valve, and was probably simply produced by the fact that the atoms of petrol had accumulated there. When there was a current of air sweeping in through the induction valve, it seemed to him improbable that lubricating oil could be the cause of the deposit. He afterwards discovered that the gentleman was at the same time experimenting with a new spirit to which he attached very great importance, with a gravity of 0·850. He (the speaker) had that spirit examined, and he had some tables with him which showed something about that stuff. Those tables compared very nicely with Mr. Brewer's table, The first drop of the spirit was got at 143° F. = 63° C.

He had learned much that evening, and he thanked Mr. Brewer for his very interesting paper.

Mr. Bridges Lee said that the author of the paper had not said very much about the composition of petrol. He could not help thinking that a great deal of the stuff sold in the market as petrol must have a very varying composition at different times. It was a distillate, and a distillate from a number of different kinds of crude material. The composition must, he took it, be very variable. Certainly the specific gravity alone could not be taken as a satisfactory or in any way complete test; nor could the boiling point of the petrol, or even the two together. What was really required to be known was the composition of the material. The material should be fairly constant, and the boiling-point should be constant throughout, until it was nearly all evaporated. With a substance like alcohol, or a substance like benzol, they might have a liquid with a definite specific gravity and boiling-point, which would not, like petrol, be made up of different substances mixed in various proportions, some of them of higher, and some of lower specific gravity, so that, the mean being the same, the composition might be very different indeed. Similarly they might have a composite liquid which had a certain flash-point, and which appeared to boil at a definite temperature, but, after it had been boiling a little time, some of the volatile elements would have gone off, and the boiling-point would be raised. He took it that the tendency as time went on would be for people to aim at greater and greater scientific accuracy and precision in the matter of liquid fuels, as in the matter of explosives and other branches of applied science. He would ask Mr. Brewer whether he ever thought of trying an admixture of benzol and alcohol spirit vapour enriched with benzol spirit vapour in different proportions.

Supposing that petrol was to be the staple substance for some time to come for driving motor cars, and supposing the demand for petrol became progressively greater, the quantity of material over must be very great indeed, and, unless a ready market could be found for it, the price of petrol, in the nature of things, would have to go up. As regards the supply of liquid fuels of any particular degree of volatility, in a general way almost any vegetable matter, distilled at a sufficiently high temperature, would give a quantity of fluid of pretty considerable volatility. He could not help thinking that the tendency in the end would be to enhance the practical value of fuel materials whose composition was known exactly, so that people might not be left at the mercy of all sorts of scratch materials with a more or less vague composition.

Mr. C. M. Hunter said that one matter which had not been referred to very much that evening, was the question of the cost of petrol. He had been an owner of a car for a few years, and had felt like many others that the price had been gradually rising and rising until the pleasure of driving was very much interfered with. In England they had no means, or very few had, of knowing much about how petrol was obtained, and few appreciated the great cost attached to its production. One question which had to be faced was the question of trying to prevent evaporation. When they had crude oil, and stored it for over twenty-four hours, they had to be prepared for a very considerable loss which was put down to evaporation. That loss was made up entirely of the lightest, that is the benzine fractions. The producer had to remember that fact, and charge something more on account of the loss. The question of the specific gravity of petrol had also a very great deal to do with it. Until recently the public had resented every increase made by manufacturers in the weight of petrol. The effect of that upon the quantity available in the world was enormous. If petrol, of say 0·720 sp. gr. was taken as the basis, the world's average percentage of petrol was necessarily low. If that was increased by 5 degrees to 0·725 sp. gr., the increase in the supply would be marked, and with every additional 0·005 the available quantity of petrol would be very considerable. This matter had been referred to at great length by the committee of the Motor Union, and it was a point which the public must bear in mind if they wanted to keep the price of petrol down. If a carburetter could be designed to work satisfactorily with a higher specific gravity petrol, the question of the supply and the question of cost would be very much simplified. In Russia the quantity of petrol available was very small. He was not quite sure what the supply was, but it was only one or two per cent., and it was used locally as fuel. They therefore could not look to Russia as being, in any way, able to supply motorists in England with petrol. It was consumed locally, and it would be consumed locally as long as the price of crude oil stood at its present high figure. In Roumania the production of crude oil was monthly increasing. It was not so long ago when it was about 200,000 or 300,000 tons per annum, but, in the present year, there was every prospect of it considerably exceeding a million tons. The percentage of benzine or petrol that can be extracted from the crude oil was considerable, seven or ten per cent., and sometimes twenty per cent. of petrol being got. The Roumanian supplies were consumed largely by Austria, Germany, Italy and especially France. As to America, the output of petrol could nearly all be consumed on the spot. This was largely due to the fact that the demand was increasing more rapidly than the supply. In the old days, Pennsylvania and Virginia supplied the world. At the present time, though the production was decreasing in the Eastern territories, it was increasing in the Southern States, where unfortunately the crude oil did not yield much petrol. Similarly, Texas and California turned out an oil which was not suitable for the production of petrol, in fact, the crude oil was so heavy that it was only suitable as a liquid fuel which would take the place of coal. In recent years a new field has been developed in the States in the Indian territory in Oklahama. The oil found in that field was eminently suitable for the production of light benzines and kerosene, but, unfortunately, before it could be put aboard ship, the price was so high that to bring it over to this country and to Europe generally, was difficult. So consumers had to go back to Borneo, Sumatra and Java, where, there was no doubt, there was a large area of petroliferous land ready to be exploited, but the demand for the heavy products was said not to be sufficient to justify the production being pushed ahead so as to supply Europe with light gravity oil.

In replying, Mr. R. W. A. Brewer said, he did not think that this subject had been treated previously or discussed from the point of view in which he had now dealt with it.

A question had been asked as to his use of the word "residual." What he had called the residual was the portion remaining after any particular distillation. Throughout the majority of his remarks he had used the word "residual," not in its true sense, but as meaning what was left after a certain fraction had been distilled from the crude. When he stated that so much had been distilled below 150° C., that portion which was left he termed the residual.

As regarding the temperature of 350° F., he took that point arbitrarily. One might consider that it was where the paraffin started, and that minimum temperature would be considered, he thought, quite safe on board ship. He did not think that they would find dangerous fumes coming off from any of that liquid to any marked extent, if it was spilled, as would be the case if they utilised the ordinary crude. In a locomotive they could do that, because there was plenty of free air, but the vapour coming from a petrol or an oil, being heavier than air, lurked about bilges, and would become very dangerous on board ship if the lighter fractions were left in. Such an oil would enable the distillers to extract all the petrol and market profitably all the remainder.

Mr. Duckham raised a point about the mixture of two liquids. He mentioned a 300° F. and 500° F. mixture. He (Mr. Brewer) had experimented with mixtures of paraffin and petrol, which were somewhat similar, and he had utilised them over long distances. The paraffin oil that he used was an oil called Bear Creek, and he mixed it with various proportions of Pratt's spirit which was obtainable at the time, and, after doing this, he got very fair results. He might say that, starting from cold, he got these difficulties of precipitation, and had to get the whole engine fairly well warmed up first. When that was done, he got a behaviour which was similar to the behaviour of 0·780 Borneo, which spirit he did not think was on the market yet.

Of course, one must have a carburetter which atomised, in order to be able to make use of it at all.

Mr. Duckham asked why it was that the commercial alcohol, although its distillation figure was so very much below that of the Borneo spirit, took such a long time to evaporate. Alcohol required a certain amount of heat. It was one of its peculiarities, and one of its properties. He believed that it was something like 10 per cent. of the total heat which it produced by combustion. He found that, when the higher temperature was reached, viz. 145° F., the heat absorbed would have a marked effect on the evaporation of alcohol. Here the difference between 170 seconds taken with a temperature of 80° F. and 60 seconds taken when the temperature was raised to 140° F. clearly demonstrates the effect of the temperature upon the time taken to effect evaporations. This effect is more marked in the case of alcohol than in that of petrol, but owing to the range of his apparatus being limited, he was unable to reach a temperature when the times taken by the two fuels were equal. The point was reached, however, when the time taken by the alcohol under treatment was less than that of the petrol or benzol without external aid.

Mr. McKinney had asked whether he had made experiments with a single variable instead of two variables. His reply was that the table referred to, represented only the abstract of a very large number of experiments which he had undertaken. From what was stated in the paper, it would be seen that the effect of air-current was very small. The results shown were a very fair example of the whole of the results. V was variable as well as the T in the apparatus which he used for the purpose. He must have an air velocity in order to get a decently high temperature adjacent to the experimental specimens. He had used various sorts of paper for these evaporation tests, which account for the differences in the times given in the table on the wall, and that given in the paper itself.

As to the carburetter loss being as high as 15 per cent., Mr. Duckham explained it to a very great degree. In some cases a good deal of the petrol is carried right through the engine into the exhaust. There was no doubt about it. They also got bad mixtures. One might probably get what was known as a too rich mixture; too much petrol being introduced owing to the variations in the jet, so that undoubtedly, more petrol went into the engine than it could economically burn. That was one reason for the loss of 15 per cent. Another was that in the arrangement of the inlet pipe, the failure to fire correctly caused blow-backs right out of the carburetter. The loss could be reduced by fitting a length of induction pipe on the air side of the carburetter. If there was a small blow-back, a certain proportion of the carburetted air would be returned to the engine, but it was not in its correct proportion, because the mixture would be further enriched when the air was partially carburetted.

With reference to the experiments on benzol and the level in the carburetter, what he did in experimenting with any different fuel, was to take the carburetter top off and regulate the petrol level to a constant point. That was easily done by weighting the float or by any of the following means. Sometimes one could move the weight upon the spindle which spindle, was the valve admitting the petrol into the carburetter. If one put the weight lower down, or further away from the valve, one would get the same effect as if one weighted the float. In the case of benzol in the particular carburetter which he used, he employed lead washers of various sorts for the purpose.

Benzol was said to be richer (if one might use that word) than petrol by 12 per cent. Therefore more air was wanted, or less liquid. The proportions of air to liquid in the case of benzol were almost self-regulating. If one went into the question of the thermal value of the different fuels, and various other points in connection with the carburetter, one would find that there was very little difference in the result of using benzol or petrol as regards the proportion of air and liquid which are obtained in any one particular carburetter. It was as well to have an extra admission of air, and it was practically essential if they were going to carry out any experiments over wide ranges, such as he did. He had a hand-regulator, and he could regulate the amount of air to any degree he wished, but he found that he did not use it to any appreciable extent.

He wondered whether the upward viscosity of benzol through a jet was the same as petrol. By that, he meant whether a certain suction would induce through the same small aperture the same quantity of petrol as it would of benzol. His theory was that the upward viscosity was greater in the case of benzol than in the case of the ordinary 0·720 petrol, so that that fact had a retarding effect upon the benzol as it passed through the jet.

Mr. Booth mentioned the carburetter loss of 15 per cent. He (the author) had explained that in dealing with Mr. Duckham's remarks. There was, undoubtedly, a certain loss in the carburetter, but, with a more efficient carburetter and a special arrangement of the inlet pipes, the loss became rather smaller. He had heard it stated that a 50 per cent. loss was no uncommon thing, but he did not agree with this unless the engine was very badly designed. He should say that something between 5 and 15 per cent. would be found in ordinary practice.

As to the thermal efficiency of alcohol, he had given on page 174 the figure of 30 per cent. which he had obtained from a reliable source. He believed Professor Vivian Lewis gave that figure in his paper on alcohol, read some few months ago, and 21 per cent. in the case of petrol. They never got anything like 21 per cent. in the ordinary small engine, but it was quite reasonable to expect very much higher efficiency in the case of alcohol than in the case of petrol.

Deposits in the cylinder were caused by various substances. Mr. Duckham had found that the deposit in the cylinder had consisted to a very great extent of dust from the road; and one could obtain a binding fluid for the dust, either from the lubricating oil, or from any impurities that were left in the spirit. One could not really state, in a haphazard way, the causes of the deposit.

A very large deposit of oil-bearing shale had been discovered near Sydney. Scotch shale produced only a few gallons to the ton—something like 30 gallons, but the oil-bearing shale in Australia produced something like 100 gallons a ton. It was easily workable. Large works were being put up for the recovery of the Australian shale oil.

There were large schemes on foot in Sweden and elsewhere for the distillation of alcohol from peat, and the persons who were responsible said that the alcohol could be produced at about 3*d.* a gallon on the site, a very low figure.

Mr. Bridges Lee had drawn attention to the composition of petrol. All the petrols were very complex, and even if the lighter fractions were distilled off below 150° C. and what was left was used, up to a certain higher boiling-point, they would have the whole of the portion of this liquid distilling over at various temperatures. However they went through the range they would always get different distillation points right through the whole liquid, so he was unable to see, in the case of petrol, how they were going to produce any volume of distillate which would come off at the same temperature. It would be very useful if they could do so, but he did not quite see how it was to be done.

He had, during the last eighteen months, made a number of experiments with varying proportions of alcohol and benzol and various other mixtures of fuel. He believed that they had done a good deal in France, and that put him up to it in the first instance. He got very fairly good results, and he hoped for better when he could alter the engine to suit the alcohol.

APPENDIX.

The formula appearing on pages 164 and 165 of the paper may be considered applicable to the usual type of touring car irrespective of its size, and the results which should be obtained in practice are given in the following table which is worked out for values of

$$\frac{\mathrm{E\,V}^2}{\mathrm{C} \times 1000} = 10.$$

and $\mathrm{E}^2\mathrm{V}$ therefore = 10,000.

E = Miles per Gallon.	E^2	V = Average Speed in Miles per Hour.
16	256	39·0
17	288	34·7
18	324	30·9
19	360	27·8
20	400	25·0
21	440	22·7
22	485	20·6
23	530	18·9
24	576	17·4
25	625	16·0

Further experiments as to the rate of evaporation of alternative liquid fuels have been carried out by the author in the manner described on page 166 of the paper, and the results obtained show that, although the boiling-point of alcohol is below that of petrol, it does not evaporate as readily, but that the application of heat is required. In the experiments the temperature was reached at that which the alcohol evaporated as readily as the petrol did when cold, and the effect of the application of heat is shown in the following table:—

Time taken in Seconds for Complete Evaporation.

Temperature. Velocity, ft. min.	T = 75° F. V = 0.	= 80° F. = 200.	= 130° F. = 320.	= 145° F. = 450.
Fuel—				
Shell, 0·720	85	36	27	21
Borneo, 0·760	90	38	27	21
90% Benzol	75	38	27	21
Commercial Alcohol	280	170	95	60
Alcohol Mixture	240	95	75	42

Larger samples of each fuel were taken in these experiments than in those referred to in the paper.

November 4, 1907.

JOSEPH WILLIAM WILSON, VICE-PRESIDENT,
IN THE CHAIR.

BRIDLE ROADS IN THE WEST INDIES.

BY H. C. HUGGINS, M.S.E.

THE object of this paper is to demonstrate a few economical principles pertaining to the method of construction and maintenance of natural-soil hillside bridle roads in the West Indies.

INTRODUCTORY.

The author, who recently had control of Public Works in the Island of Tobago, B.W.I., has been afforded some opportunity of studying the question of this class of bridle roads, their construction and maintenance. There is an historical interest in the roads of this West Indian island, inasmuch as during the French occupation, they were originally laid out by their military engineers. In fact, nearly all the principal roads in the Colony today may be said to have been founded on the old French tracings. It is not the intention of the author to deal with the subject of road tracing; it is assumed, for the purpose of this paper, that the engineering reader has already some knowledge on the matter. It is, therefore, proposed to take these old French traces, so excellently graded, as we find them, and endeavour to convert them into serviceable bridle roads. Indeed, merely to open out these forest clad tracks, and to render them into a means of outlet for produce, or to tap unsold acreages of Crown lands, is the object of the authorities for the present—and until the prosperity of the island warrants their conversion into cart roads.

The whole of the island, with the exception of the S.W. portion, is very much broken up into hills and valleys, rising in height towards the N.E. These old traces skirt the hill sides, winding their irregular way with weary persistency. Except where the old French tracing has been abandoned for a steeper and more direct route, the former grading remains to-day a relic of the past, when the power of France penetrated even into this far away island.

Sectional Formation.

Figs. 1 and 2 may be taken as representative of two recognised sections in road construction; the dotted line in each case indicates the remnant of the old French tracing as found today. A glance at Fig. 1 will show a method of reconstruction disastrous to pursue in forest lands where the alluvial soil is impregnated with vegetable matter. Cutting taken from the slope A is embanked at B, the road being thus formed to the required width. A minimum amount of excavation is thereby done in proportion to the total width of roadway. It is easily conceived how the filling at B is liable to become loosened and soft under heavy tropical rains, and eventually form a veritable bog during the wet season, rendering traffic dangerous, and at times impossible.

Fig. 2 demonstrates the most satisfactory method of formation. It will be seen that a clean cut is taken out of the solid bank with a 4-inch slope inwards for a 6-foot wide road, taking care to start from the outside edge. The surface thus obtained is found to be far more lasting and substantial than any made of filling, however well rammed. Filling of this description, unless subsequently sheeted with metal or other road material, must develop into a mud road in the rainy season, no matter how efficiently provided with drains the road may be. It must be borne in mind that during a tropical downpour lasting many hours, the whole roadway may be water-soaked, the drainage being incapable of coping with the overflow. It is important to remember that the author is dealing with natural soil roads. Many remarks made by him in this paper would be obviously hardly applicable to metalled roads.

By reference to Fig. 1, the side drain is found to be somewhat a mistaken advantage. It is clear that for a drain to be of any use it should be at least sufficiently large to carry off the volume of water likely to collect in it. The quantity of water (generally referring to the tropics) from the hill sides together with the surface water from the road is by far too great for the size of drain which can be properly made on a bridle road. Moreover, the detritus from the hill sides soon clogs the drain, and when this happens it is usually far too costly a job to deal with properly on an emergency, especially where many miles of road are concerned.

By means of the inside fall, Fig. 2, the side drain is dispensed with to advantage. The surface water flows easily towards the banks, and follows the natural gradient of the road till thrown off by the open cross drains. The loose soil obtained from the cutting, Fig. 2, is banked upon the outside edge as at C, forming a parapet about 2 feet high for the safety of the traveller. The importance, however, of this parapet from an engineering point of view is the preservation of the outside edge from slipping or breaking away, a likely occurrence due to the percolation of rain water when the ground is sodden, and the overhead drippings from trees. Whilst it is not contended that this method of banking is an infallible safeguard against slipping, it is maintained that this evil is eliminated to a considerable degree.

A back bevel of 2 : 1 will be found to be a convenient slope for the banks, but this must of course vary in accordance with the angle of repose for different soils. Where the banks are high, or the soil very loose, it is more economical to bench back, as shown in Fig. 3, than to reduce the angle of the slope to any great extent.

The innumerable streams which necessarily fringe the hill sides and intercept a mountain road, call for special attention. These rivulets, which are insignificant in the dry season sometimes swell into torrents and miniature waterfalls after the rains set in. These require to be carefully paved with flat surface stones laid with an outward fall (Fig. 4). At larger causeways, over which are conducted a greater volume of water, the road should be protected from inundation by rubble or concrete retaining walls. These walls should be carried up to a sufficient height above the road level to allow an arched opening for an outlet as shown, Figs. 4 and 5. Provided that this opening is made of a size compatible with the outflow, it will be found that for those roads, on which economy in construction renders the cost of culverts prohibitive at the moment, these temporary works can be utilised to advantage, and culverts may eventually be put in. It is plain that the culvert has to be built only of the same size as the opening.

FELLING.

Trees must be felled to clear the track and to admit light and sunshine, both valuable accessories in keeping the road surface dry. All unsound and dangerous trees which are likely to become a menace to public safety must be cut down. But the felling of trees is often done in excess. The author has seen trees cut down to 80 feet or more on either side of a forest road by well-meaning road makers, with the desire to get as much sun as possible on the roadway. Large forest trees need not usually be cleared for more than 25 feet on either side of a permanent bridle road, whilst smaller trees should be left standing as near as possible, as these are useful to safeguard the banks from slipping. The fact that surrounding vegetation does its share in absorbing the moisture from the road surface is apt to be overlooked.

Experience soon teaches the road maker that some trees are better than others for this purpose, and these should be carefully preserved. The Bamboo tree, so abundant in the West Indies, is perhaps the most useful of all in these Islands for its power of absorbing moisture, and deserves special notice.

For such roads as are likely to become cart roads in the near future, the clearing of forest land should be made to the full distance in the direction of the cutting, to allow the extra width of roadway to be made. This would be, in the case of a permanent bridle road, in addition to the 25 feet clearance recommended previously.

Thus the clearing for a bridle road 6 feet wide, which it is anticipated will be formed into a 20-foot cart road, should be about 45 feet on the cutting side. Neglect in this direction results in a heavier cost in further felling later on, apart from the danger involved in carrying out such work after the line has been once established.

SUBSIDENCES.

Landslips in a country of this nature are inevitable during the rainy season of the year. They cannot often be predicted, and in the case of an overhead slip there is little to be done in most cases save to clear it away, taking care that no other loose or dangerous stuff remains above. The cause of a road slip should be always carefully examined and at once remedied. Fig. 6 represents a common form of such a slip, due to a subsidence at A. The lowest point of the subsidence should be always carefully located, and stakes firmly driven in along its entire length. The slip can be then made good (as shown in the hatched portion) and benched if a long one, and should be eventually planted with some suitable grass or bamboos to render the mass compact against further slipping.

An example of a landslip of a more serious nature is given in Fig. 7, as not only was the road destroyed, but the safety of a building involved. The occurrence took place at the police station at Scarborough (the capital of Tobago). Here a narrow bridle path 3 feet wide skirted the premises at the back, where the land slopes abruptly down 40 feet to the sea below. The whole of the pathway suddenly slipped (Fig. 7), and the safety of the building was thereby threatened. The building and path in question are situated at the foot of a hill 500 feet high and half a mile inland. The geological formation of the hill is of a loose clayey nature. Practically the whole of the subsoil drainage percolates this lower portion, and the weight of the building thereon tends to unduly compress the mass, the result being a tendency to slide at the base. These causes were hastened by the erosion caused by the sea at the foot of the cliff, and some exceptionally heavy weather to which the whole surface is exposed. After clearing away the loose stuff the natural slope assumed the line indicated. The total length of the base of the slip was 70 feet, and a surcharged retaining wall was built the entire length, each end butting into the rocky cliff formation. The height of the wall was 10 feet, and substantially built in the manner shown to withstand the sea as well as the weight of the filling behind it. The filling used was selected dry earth well rammed to a slope of 1·37 to 1, and the whole planted with suitable grass.

The stability of the wall is demonstrated graphically in Fig. 8, where it will be observed that the resultant of the thrust and weight cuts the base within the middle third at ground level X, which is for practical purposes a safe position for stability. Also the wall is located, so that the weight of the building lies beyond the limiting line of rupture, viz. half the angle formed by natural slope of the earth and a vertical line which is in this case the back of the wall. By this means the wall is relieved of any load caused by the weight of the building behind it.

Three rows of weep-holes were provided, the lowest line of which was 18 inches above high-water mark to safeguard the filling from being gradually washed out by tidal movement. The wall was of rubble masonry with pure cement joints 2 : 1, built on concrete foundations, the lowest face being bonded with selected stones, as shown in Fig. 7, to a height of 3 feet to better withstand the sea at the highest tides.

To facilitate careful working the excavation and foundation work proceeded at low tides in sections, the foundations being laid on a rocky stratum. The pathway above was finally made up on a boulder bed as indicated in the upper portion of the sketch.

Reference has already been made to the many small streams intercepting a mountain road and eventually discharging themselves into some main water-course. These water-courses are frequently practically dry during the dry season, but expand into formidable rivers after the rains set in, and carry all before them.

Fig. 9 illustrates the subsidence of a road due to the attacks of such a river. The economical method of building out a groyne at A may be successfully adopted after the rainy season ceases, and the river runs low, in readiness for the next wet season, when the river is deflected into another direction. Such groynes can be cheaply made in most cases from lumber cut on the spot. The structures can be regarded only as temporary, and to be discarded after having done their work. With larger water-courses it may be necessary to employ a groyne of more substantial build; in which case a very economical and effective one can be made from old rails driven into the river bed, faced with planking (Figs. 10 and 11), and built to a height of about 6 feet. The length of such a groyne in each case must be governed by special factors dependent upon the velocity of the stream, width of water-course, and curvature of the banks. The author has found in most cases that for practical purposes if the extreme end of the groyne be built out to one-third the width of the course (taken at right angles to the banks), the best results are derived. The groyne should be then built back towards the bank with a slope in the general direction of the proposed diversion, giving the least possible angle of resistance to the stream. (Fig. 9.)

BRIDLE BRIDGES.

For a bridge for bridle traffic, where the span does not exceed 14 feet, two 9 inch by 3 inch hard wood runners, supported on ground sills (Fig. 12), are found to be sufficient. The width of such bridges need not exceed 3 feet. If greater spans are required the booms should be trussed (from above in preference) for the sake of economy, rather than the size of the timbers increased, as it is evident that heavy runners would require substantial piles or concrete abutments for their support. It is very desirable on these narrow bridges to have the rails boarded up on the inside (Fig. 15) as a safeguard against a horse's foot slipping over when the timber decking is wet. For economic reasons the expenditure on public works has to proceed with the progress of development in a country where many of the bridle roads may be regarded as forerunners of cart roads. These bridle bridges must in the course of time be replaced by heavier structures to meet the increase in traffic weight, and substituted by those made of concrete, iron, or heavier timber. It is, accordingly, well to avoid as far as possible putting in permanent work such as concrete foundations, walls, etc., which may become a source of obstruction to other structures eventually, that may be found necessary.

In a country where the temperature is about 80° F. with little variation, and the expansion and contraction of materials inconsiderable, the ordinary steel railway rail may be utilised for constructive purposes to a degree which would be scarcely warranted in a climate subject to extremes of heat and cold.

The following is a description of a bridle bridge, 23 feet span and 3 feet wide, built almost exclusively of railway rails. Several bridges of this type have been designed and erected by the author, and have proved quite successful. He has, for practical purposes, treated the tensile strength of a rail girder as being equivalent to that of a steel joist of the same sectional area, cognisance being taken of the decrease of compressive resistance in the head of the rail (or top flange). The comparative extra strength of the web of the rail to resist vertical shearing has been regarded as a factor on the safe side. The rails used were 55 lb. per yard in weight. Fig. 13 shows two rails firmly riveted together by their flanges (rivets 12 inches apart) to form piles, their ends being pointed for driving. The piles were driven to a depth of 14 feet with a ringing machine. It is important that the top surfaces of these rails should be quite flush, so as to avoid the rivets being strained on the fall of the ram. The driving had to be done carefully with a ram of native hardwood of about 2 cwt., banded with iron straps. Thus the head of each pile was in no way injured or unduly compressed, and this enabled the longitudinal girders and brackets to be easily and properly fitted. Each pair of piles were then stayed together by braces composed of 3 inch by ½ inch iron bars (Fig. 15). A pair of rails were then laid across the head of each pile to form longitudinal compound girders, and secured by angle pieces to the flanges and webs as shown. Another rail with flange uppermost to receive the timber decking pieces was then placed between each pair. Care should be taken to ensure the rails being perfectly straight, so that they may interlock properly. Attention is directed to the long bolt A, Fig. 15 (one at every standard), which clamps the stringer to the decking and flange C below. To replace a bad decking-piece, it is only necessary to loosen the long bolt A, the piece can be then withdrawn and a new one easily inserted. This will be found to be an improvement on the principle of letting the standards into the stringer (Fig. 16), thus necessitating the removal of both to renew a decking piece. It will be observed that the decking pieces are merely let on to the rail flange, and are kept in place by the stringers, ¾-inch cleats being provided between each piece. This light mode of superstructure was found to be ample for the little vibration to which a bridge of this kind is subjected.

The bridge may be built in two spans in a similar way with a slight modification in the placing of the centre piles, where provision must be made for a hard-wood cap to receive the four girder ends, and the piles reversed to give a fairer bearing on the cap.

The bridge is calculated to carry a safe distributed load of 200 lb. per square foot. The $\frac{3}{8}$-inch bolt connection with the flange at C is perhaps the principal weakness in the structure, being subject to a shearing force which might prove disastrous were not the bridge wholly confined to light traffic, for which it was designed.

DISCUSSION.

The CHAIRMAN moved a vote of thanks to the author which was carried by acclamation. The paper had been written with a knowledge of the requirements of the locality to which it referred, and dealt with minor matters, yet, at the same time, an engineer had, of course, to adapt the means to the end; and, as the author had pointed out, he was not so favourably placed as are those engineers who are not limited altogether as to the amount of money they can spend. He hoped that fact would be borne in mind in the discussion.

One or two points had occurred to him in reading the paper. The laying out of such paths as those described was an interesting branch of engineering. Doubtless those present had seen lately that, in the north-west of Canada, a very long bridle road had been run by the Dominion authorities in order to open up the far north-west districts pending the time that a railway could be made which he believed would not be for some years to come. In a letter which he had lately received from that part of the world it was pointed out that one of the great difficulties of the engineer was the fact that he had to carry the roads through forests that had never been explored, and that were unknown to any but the Indians, where many centuries of trees had fallen and died and left their trunks and boughs lying about in all directions, so that it was almost impossible to make progress through them. This added very greatly to the labours of the engineer, not only in making the roads, but especially in the preliminary exploration and location.

On looking at Fig. 2, Plate I., he observed that the author showed the new slope he had made, and that he had put the excavated stuff at C, laying it upon a dotted line which represented the section of the old French road. Presumably, that dotted line represented the natural slope of the material, and, if that were the case, it seemed to him that the author was rather sanguine in hoping that the material at C which he had put on, and which took a much greater angle, was likely to remain in that position very long.

Then, no doubt, it was a rather serious problem which they saw shown on Plate II., Fig. 7, where the slip had occurred, and apprehensions were naturally felt as to the result, he could hardly see why the building should have been put so close to the top of a slope of that kind. It appeared to be a rather bold proceeding if there were any option in the matter.

There were many points in the paper which he hoped the meeting would be able to discuss. He was glad that they had Mr. Ernest Benedict present, and he had very kindly promised to open the discussion.

Mr. Ernest Benedict said it seemed to him that the paper, although it applied to what might be called a very small matter indeed, involved principles that applied to all roads on sidelong grounds, whether railways or otherwise. Such roads always gave a great deal of trouble. He would deal with the sketches one by one. The first one that struck him was on Plate I., Figs. 1 and 2. As the Chairman had pointed out, the author had always, or very nearly always, steepened the slope of the old French trace which, he presumed, was found the most suitable for many years. It seemed to him that this was courting disaster. Many of the places which he described were in a state of unstable equilibrium, so that the very slightest interference with the natural slope or angle of repose would start a slip. People did not realise what they did in *starting* a slip. It was comparatively easy to prevent a slip, but almost impossible to stop one, because the enormous masses that were set in motion—very slowly indeed, sometimes—could not possibly be stopped by any structure within reason; they could only be stopped by counter-weighting or counter-balancing. A very good example of what enormous weight would do was given the other day, when a large liner practically cut a solid breakwater in two. It was not going at any great speed, but the enormous weight and consequent momentum of the vessel took it right through the pier. Let them take, for instance, the section in Fig. 1. The weight of the earth which would probably be set in motion at A, supposing the hill to be a high one, would be something enormous, and it would be quite beyond any power to stop it without the expenditure of a prohibitive amount of money.

With regard to the lump C in Fig. 2, he had no doubt that it was made up of sods which were really more solid than the rest of the ground, or else, as the Chairman had said, it would be rather a source of danger than otherwise.

Plate II., Fig. 6, showed a case where stakes were placed at the foot of a slip; a great mistake was made in trying to stop it in this manner. There was a case on the Great Western Railway where there was a slip which went right up to the top of the hill. They drove 12-inch piles along the toe of it, and those piles seemed to hold it, for they kept upright, but, on investigation, it was found that, although they were upright, they had actually been sheared off, so that the tops were travelling with the slip; they had not stopped it in the least. The stakes in the diagram were a case in point. If, instead of putting those stakes, Mr. Huggins had slightly steepened the top slope, and then put a rough stone wall, as he had done in Fig. 8, it would have been very much more effective.

It would have been interesting, both in Fig. 7 and in Fig. 6, if the author had given the original surface line before the slip occurred, but he had not done this in either case, and consequently, it was rather difficult to judge of the severity of the movement. But here, again, he considered that the greater portion of the earth filled up above the dotted line (which they had been told should not be in the diagram) was, not only useless, but harmful, and if it were trimmed off to something like the slope of the back, which was very nearly vertical, and revetted with loose stone walling, the bench thus left would act as a weight keeping down the earth, and effectually counterbalancing the lightened top.

As to Fig. 9, unfortunately for himself, he had had a great deal of experience of river training. There were two things which he wished to observe with regard to the sketch in Fig. 9. One was that, if they shortened the course of a river by simply cutting between one point and another, they would find that, unless they took further proceedings, they would not do what they wanted to do. The new course being shorter—and he was taking it for granted that it would be shorter—the water would run faster than the water in the old course, and, when it got back to the old course, it would be suddenly checked, and would deposit silt. If it was a river without silt, his observations would not apply. He had had a case in Bengal in which they made a very deep cut (in the dry season) from a big backwater in a large river into a little river, in order to divert part of the water into the smaller river. This acted all right when the rivers were high, but, to his astonishment, when the water went down again, the big river went round its old bend, and silted up the mouth of the cut.

Then, again, with regard to the groyne A, there would be bound to be a backwater. It would be seen that there was a concave course on the left bank of the river, and the cutting away of the new course would not prevent the water from swilling round the end of the groyne A and actually aggravating the original evil. If a straighter course had to be cut in a river, they must begin a long way down, and deepen the river up to the outlet of the new cut, or else it would be found that the work was inoperative. To his mind, the way that the bank should have been treated would have been by simply throwing rough stone into the old course and by filling up the little bend, always supposing there was plenty of stone there.

Concerning the driving of piles. The author correctly stated that it was very important to have the heads of the rail-piles level, because, if one stood up a little higher than the other, the blow of the monkey would shear all the rivets. He had a very good example of this when he made a boat-wharf at Karachi in India. There was a large number of old double-headed rails to be had very cheaply, and he made piles of a group of the rails. He took seven of them, and put rivets through them nearly six inches long. Everybody said that what he was doing was perfectly ridiculous, and that the rivets would all be sheared if they drove the thing far. He had to drive the group of rails through the worst stuff in the world, namely, sand and gravel mixed. He made the native contractor who had the job use a 30-cwt. monkey, and the trigger was placed so that the monkey could not be raised more than six feet. The consequence was that, to everybody's astonishment, the rail-piles were driven through the sand and gravel without a single rivet going; the whole principle being, that as the old saying is, you cannot drive a tenpenny nail with a sixpenny hammer, because you will simply smash the top of the nail and perhaps the hammer also. Of course, it did not matter how heavy the hammer was; you could drive a tack with a 10-lb. hammer. It was on that principle that people should go when pile-driving, but it was very seldom that they did. Consequently, the head of the pile got fluffy, and there was a lot of trouble with it.

In conclusion he would go back to Fig. 1. The author said that the little side drain on Fig. 1 was about the worst thing that they could possibly imagine; but in his (Mr. Benedict's) experience, side drains generally were put along the inside edge of such roads. It stood to reason that the steep dip on the left-hand side of the side drain would actually encourage slips, and, not only that, but the water in the side drain seeped under the road and generally caused slipping; so that there was nothing so fatal as a side drain like that, and it ought never to be allowed. In Fig. 2, instead of making the slope inwards, he should have made the slope outwards. It was much better to let the water run from the road, if they possibly could, by making holes through the wall as shown in Fig. 5.

Professor R. H. SMITH said that he had been a good deal in mountainous countries, and he had found the study of hillside and riverside paths interesting. In the Highlands of Scotland, it would be found that in nearly every case the shepherds' paths along the mountain side had been originally made by animals. The shepherds had simply developed the tracts started by the animals. The deer and the sheep selected the shortest and safest routes, and the shepherds followed their guidance. Another kind of path genesis, also due to animals, was beautifully illustrated by the very steep bank on the Malvern Hills, between great Malvern and the Wych. The hill was covered with parallel tracks running diagonally along the hillside. These sloping terraces had really been laid out by the sheep, to facilitate their grazing upon the grass on the hillside. The series of paths ranged one above the other at such a height that the sheep, standing upon one path can reach all the grass up to the edge of the next path above. It was very interesting to note the great differences between the routes made by human hands in modern times and those made in very ancient times, and this was particularly well illustrated in the South of England. The old Roman roads and the old Saxon roads followed routes whose courses were almost wholly explained by the ancient necessity of steering clear of extensive marshes which had disappeared entirely in modern times in consequence of the cultivation of the land. This largely explains why the old Roman roads run straight over hill and dale, avoiding low ground and hardly ever running along the valleys.

He agreed with the Chairman that the parapet C, in Fig. 2, was not advisable. As the last speaker said, it was most desirable to get the rain off the paths as quickly as possible, and over the outer edge of it.

He was inclined to agree with the objection made to the staking at the foot of the bank. A long series of stakes driven in a more or less straight line in a dangerous place, was more likely to develop a crack than to prevent one.

The felling of trees was said to be done only for the sake of light and air and the drying of the roadway, both of which objects were excessively important. He would suggest that it would be well simply to cut down trees near the ground and to leave the roots in, because the roots were the most valuable kind of fastening to hold the ground together that they could have.

The most interesting bridle path that he ever saw was in the Yosemite valley in California. There was one place where the path descended over two thousand feet in level in less than half a mile of horizontal distance. It led down into the valley at the western end of the tremendous precipice which overhung the Yosemite Hotel. This precipice ran sheer down almost perpendicularly for a height of two thousand feet, and then at a slope of something like 40 degrees for another thousand feet underneath that. The path zigzaged constantly and there was a great deal of dry-stone building up between the zigzags. The stone wall rose from one zig of the path right up to the edge of the zag above, with a batter of perhaps only 1 in 8 or 10. These paths seemed to have stood for a very long time without repair. They were very steep. The gradients of the path must have been at least 25 degrees from the horizontal. It was excessively steep. The paths were very stony, but for that reason, perhaps, the water got away very readily, and of course the water got through the dry stone walls with great readiness without carrying any of the soft material with it. The whole bank was excessively rocky, but was well covered with forest trees.

Regarding the criticism made of the undercutting below the natural slope of the ground above the level of the path shown in Fig. 2, it was evident that it was desirable to place the whole of the embankment supporting the path entirely outside this natural slope. This involves giving the outside of this embankment a much steeper slope than the natural slope, and therefore the embankment must either be built of material different from the natural soil, i.e. of material to which this steeper slope is "natural," or else must be supported artificially by a retaining wall or otherwise. The trunks of trees felled in making the clearance seemed capable of being utilised in such reinforcement, these trunks being bedded in vertical planes. This wholly outside embankment also evidently involves the carrying to the site from elsewhere, new material wherewith to form the body of the embankment, and for the majority of bridle-paths the expense of such transportation of material may be prohibitive. In this case there is no alternative to undercutting the natural slope above the path. The material cut away from above the path being utilised to form the embankment below the path and outside the natural slope, and, in order to be useful for this purpose, being necessarily consolidated by ramming, and to a greater density than that of the "natural" soil, it follows that the volume of cutting above the path must be somewhat greater than that of the embankment below the path, and, therefore, that the line of the original natural slope falls somewhat outside the centre of the width of the path.

The volume of the embankment is now only less than one quarter, and its depth one-half, of that needed when it is made wholly outside the natural slope. Of course, the cutting above the path, being at a steeper than the natural slope, requires reinforcement either by a retaining wall or otherwise. If the materials of the hillside are suitable for this construction, it is evidently the most economical. It must not be forgotten that the "natural" slope varies largely with the weather, and that all ancient hillsides assume the slope corresponding to the wettest season of the year, which is very much less than the mean natural slope averaged over the whole year.

Mr. D. A. Symons said that, on a comparison of Figs. 1 and 2, it was perfectly obvious that Fig. 2 was the very much better one with the exception of the lump at C. Some years ago he was associated with a railway in the South of England where they had a cutting inside long ground similar to Fig. 2 which was in Kimmeridge clay. The drainage of the Kimmeridge clay was a difficult problem. The only way of getting over it was by not having the side drain at the foot of Fig. 1, but putting a large stone French drain down the face of the cutting at about 25 or 30 feet pitch, and ballasting the formation level right up to the toe, the water being carried away by earthenware drains placed between the sleepers, these being placed 10 or 20 feet apart. They found after heavy rains that the French drains had interlaced each other on account of the slipping of the ground. The ground eventually became consolidated, and he understood that the drains at the present time carry out their work effectively. The work was executed about seven years ago.

On Plate II. the author had given a diagram. With reference to the masonry wall—a surcharged wall—the diagram of forces could not be a rectangle. He contended that the line showing the pressure against the wall ought to be parallel to the surface of the ground, and not horizontal as shown.

The author had said that it was a pity that that dotted line on the diagram had been carried across. Personally, he thought that it was a very good thing. It showed at once that the building was absolutely outside and could not give any pressure whatever upon the wall.

Mr. ARTHUR RIGG said there was no doubt that the makers of roads were the pioneers of civilisation, and, as nations progress so must their means of communication become more important. The author had given a most interesting account of the bridle paths which seemed to be the earliest form of road-making, and these roads reminded him of corresponding arrangements in America in the Rockies in 1884. The roads were the roughest imaginable, but that was nothing in comparison with the bridges. When it was necessary to cross a gulch or valley, the largest trees in the immediate neighbourhood were secured, and where they went down so did the roads also, and the earth, or rocks, on both sides was cut down to the place where the trees had found their rest. Then on the top of the three or four trees. lay a number of short round pieces all loose and rolling about except that in some cases a few sods were there to steady them. To drive up the opposite steep roadway it was necessary to descend at full speed, and wonderfully the reckless driver brought him (Mr. Rigg) safely to the top of the opposite crest, in spite of the upper layer of short pieces rolling about under the horses' feet, and the longer trees below dancing some 2 or 3 feet up and down as the four ponies and the ramshackle vehicle rushed over at full speed. The whole thing was rough and tumble in the last degree, and nearly as dangerous as the London streets.

If we turn now to the work of the Romans. In Lancashire, near Bolton-le-moor, there was still surviving an ancient "saddle back" bridge all of red sandstone and just wide enough to serve as a bridle path or a roadway for one of the narrow carts of that period. The last preserved record, however, of a Roman bridge of considerable engineering importance, was one mentioned by Mr. Charles Hawkesley, M.I.C.E., in his address as President of the Engineering Section of the British Association at Southport in 1903. He said under the heading Liverpool, evidence of the gradual sinking of the land is given by the very interesting discovery in 1850 of a Roman bridge at Wallasey Pool, Birkenhead. After excavating 14 feet, the workman came upon a bridge of solid oak beams, supported in the centre by two stone piers, and resting at the ends on the solid rock at the sides of the creek. The length of the bridge was 100 feet and its width 24 feet, and the beams were each 33 feet long, 18 inches wide and 9 inches thick. There were 36 beams, formed into 12 compound beams, each 27 inches deep. Careful drawings were made by Mr. Snow, an engineer employed on the work then in progress. The drawings show that the rocky bed of the stream was some 13 feet below the bridge, which was itself about 16 feet below the present high water level. Incidentally, this seemed to show that the land had been sinking at the rate of about one foot in a century.

Mr. F. G. BLOYD said he thought that the paper was of a character which the society would do well to encourage. It gave Home Members some idea of the kind of work carried out in foreign lands. A great many of the recent papers had been limited to English practice. Mr. Benedict had threshed out some of the points very thoroughly, and he had alluded to Indian roads. He should like to ask Mr. Benedict if it was not a fact that on the Indian bridle paths the makers were very fond of the side drain shown in Fig. 1, but that they conveyed the water from the side drain at frequent intervals by pipe drains laid under the road. Of course, that got the water out of the side drains. He certainly thought that the construction shown in Fig. 2 was preferable. There again the idea that first struck him on originally reading the paper was that the slope of the road ought to fall outwards and not inwards, because he thought that the water running down the cliff and off the road itself would very soon scour out a drain at the base of the cliff. Again, there would be the same tendency for the water to collect at the base of the cliff and penetrate under the road, and so, in time, cause the whole road to settle or slip outwards, a point to which the author gave some prominence to in the paper.

As to the felling of trees, the author said that he had "seen trees cut down to 80 feet or more on either side of a forest road by well meaning road-makers with a desire to get as much sun as possible on the roadway." He (Mr. Bloyd) rather differed from the author. He could not speak personally on foreign practice, but a friend of his who had had a great deal to do with cutting bridle paths in Brazil, and making preliminary surveys for railways through forests which had never perhaps been entered by man before, said to him, "We never cut a single tree down, if we can help it. Cutting trees down allows the tropical rains to fall direct on to the roads and wash them away. Leave the trees up. They are the best protection for the paths." No doubt the author would say, in reply to that view, that in Tobago they got wet and dry seasons; that is to say, that they got rain at stated intervals, and then fine weather for long periods. Therefore, he should like him to say if the advantage of cutting trees down to admit light and air was balanced, or more than balanced by the damage that might be done to roads by heavy rains falling direct upon them.

Mr. Benedict had rather forestalled him by the reference he made to the piles on the Great Western line. He was going to allude to a similar instance down in the south of England where there was a rather high embankment of alluvial clay that had repeatedly slipped, until at last the slope of the embankment was about 4½ to 1. At one point there was a footpath running at the foot of the bank, and as the bank showed a further tendency to slip, it was arranged, rather wrongly as he (Mr. Bloyd) thought, to drive a line of piles along the base of the slip. The piles no doubt kept the slip back for about six months, but to-day, instead of being vertical, they had gone over, and three piles out of ten driven had sheared right off. A little further along, an exactly similar slip had been dealt with by building up a wall of block chalk. This had stood very well, and no doubt the increased weight at the toe of the slip had kept the bank from going out any further.

With regard to the outside parapet in Fig. 2, most of the speakers seemed to think that it was a mistake to put it there, but the author had said in his paper that the primary object of it was to provide safety for travellers. He thought that that, perhaps, had been rather disregarded by the speakers. There was absolutely no light on some of the roads, and the parapet was put so that a man on horseback could tell when he was on the path and when he was off. Therefore the parapet was very useful. He should say retain the outside parapet but leave openings at frequent intervals for the water to flow through. He thought that these openings and the slope of the road outwards, ought to effectually get rid of all surface water.

Mr. Benedict said that, with regard to the question which Mr. Bloyd had put, he (Mr. Benedict) thought he had mentioned in his remarks that they had cut the side drain, and that he thought it was very objectionable on the bridle paths, and not only on bridle paths, but on much more important roads.

Mr. Bloyd said that they took pipe drains underneath to draw the water off.

Mr. Benedict said that no doubt they did, but that did not do away with the evil. It minimised it a little.

The Chairman said that he was sorry that the author of the paper was not present to reply, but the members would see his reply in due course in the transactions.

In reply to the discussion, Mr. H. C. Huggins said that several of the speakers had somewhat severely criticised the side slope (Fig. 2), because it was steeper than the slope of the hill. Mr. Benedict had said that the very slightest interference with the natural slope would start a slip. Now, it is evident that unless some very slight interference with the slope of the hill is made, in order to obviate the danger of any slipping, it would be necessary to cut the slope at an incline which would be at least parallel to the hillside. This would involve an enormous amount of cutting (possibly right up to the top of the hill), and no matter how desirable that may be in point of theory, his (the author's) experience was that it would be quite out of proportion to the cost of such an undertaking. The only thing then was to cut a somewhat steeper slope which would intersect the natural slope of the hill gradually, and the most suitable slope could be determined only by actual experiment with the soil. Tables giving the angles of repose for various soils were of a qualified value when reduced to practice, because, after all the question in any given case, was whether the soil under consideration, corresponds in variety and condition, to the one in the table, and the question is ultimately one of practical judgment. In this case he had found a slope of 2 to 1 most suitable.

Another point which he thought had been overlooked, was that the surface soil in forest lands was impregnated with loose vegetable matter, and that the undercutting was generally composed of more compact material, which could therefore assume a steeper angle of repose.

The Chairman had expressed some apprehension as to whether the parapet would retain its position long, but from the foregoing observations it would be seen that this mound would be composed of the more compact soil from the cutting, which when heaped up and rammed was found to retain its position very well.

References had been made to the inward fall and absence of the side drains (Fig. 2). He (the author) knew that it was the practice to make the fall outwards, and to adopt the side drains in some countries, and he concurred with that arrangement for a cart road, where a fairly wide roadway was essential. He had tried both ways himself, and found that the method he suggested was the most favourable for bridle roads. With regard to the driving of stakes at the foot of a slip, he agreed that a wall would be preferable, but, as the Chairman had pointed out, the engineer had to adopt the means to the end, and whilst stakes were always ready at hand in a forest road, stones were not always so easily obtained.

Mr. Benedict's remarks concerning the river in Fig. 9, were of the greatest interest, for he said he had a great deal of experience in river training; the rivers, however, in Tobago were not silty, but had clean gravel or shingle beds. He stated that the groyne would only aggravate the evil because of the backwater, but he (the author) had found that this caused a gravel deposit to be gradually formed behind the groyne. When rivers are in flood their erosive action is unknowable and cannot be predicted, especially if the soil is of a loose gravelly nature, and he was therefore inclined to think that Mr. Benedict was rather too certain, that the concave bank would be detrimental to the object of the groyne.

Mr. Bloyd had rather misunderstood what he (the author) said about felling trees. He did not advocate much felling; on the contrary, he stated that it should not be done in excess, and suggested only a 25-feet clearing on the cutting side of a bridle road. Trees were very useful as a rain-break, but it must be remembered that a hillside road was generally more exposed in this respect, due to the sloping away of the hill, and received little protection from trees when that side of it was against the weather.

The Chairman had drawn attention to the danger of placing a building so close to the top of such a slope (Fig. 7). The building is a very old one; he (the author) could not say how long ago it was built; but he had reason to believe that at the time of its erection, the site was a considerable distance inland, and the position it occupies now was due to the result of years of sea encroachment.

Mr. Benedict had suggested that the greater portion of the earth filling above the dotted line (Fig. 7) was not only useless but harmful, and that it would be better to have trimmed off the slope at the back (which was very nearly vertical) and revetted with loose stone walling. This would have undoubtedly lightened up the top as he had pointed out, but he (the author) rather questioned the expediency of building up a steep slope like that some 20 feet high in that manner. This loose stone facing would be very top heavy in his opinion; the joints of the stones would require to be grouted in cement and the face of the wall stepped out, and there would not then be much reduction in the mass above the dotted line.

Mr. Symons had contended that the line of pressure against the wall shown in the diagram (Fig. 8) should be parallel to the surface of the surcharged ground, and he (the author) believed that this was theoretically correct. It must be remembered, however, that in the process of construction the earth is gradually filled in from the bottom upwards, and rammed in layers, in the direction of the length of the wall. The filling up of a large slope takes some time especially, if the stuff is not ready at hand (as in this case). By the time the filling reached to a level with the top of the wall, it would have settled into a consolidated mass, and the pressure of the wedge of earth thus formed is horizontal. He (the author) had then taken the effect of the surcharge as merely so much extra weight in this wedge.

Sir Alexander Kennedy, in his Presidential Address to the Institution of Civil Engineers last year, said, that engineering problems differed from ordinary scientific problems "in that they are much more complex, and consequently more difficult of anything like exact solution, and still more because—exact or inexact—some solution to them has always got to be found." He (the author) would say, in conclusion, that the truth of this statement was, perhaps, best appreciated by engineers carrying out pioneer work in the Colonies, where the circumstances, labour, and material at hand were not always suitable, and where economy is a great consideration.

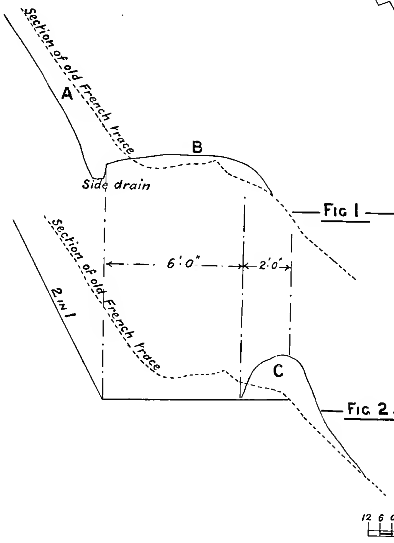

Section of old French trace
A
B
Side drain
6' 0"
2' 0"
Section of old French trace
2 IN 1
C
12 6 0 1 2 3 4
Scale of Feet

FIG 1

FIG 2

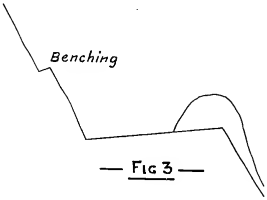


FIG 3

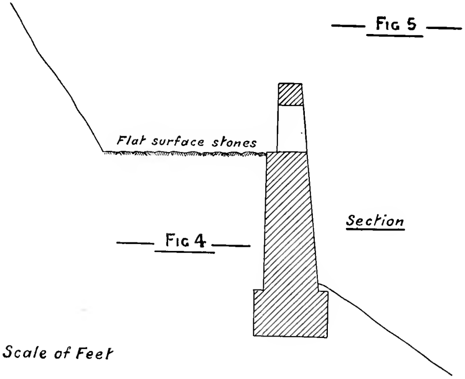

Flat surface stones
Section

FIG 4

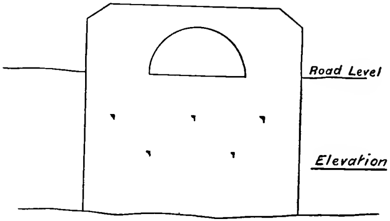
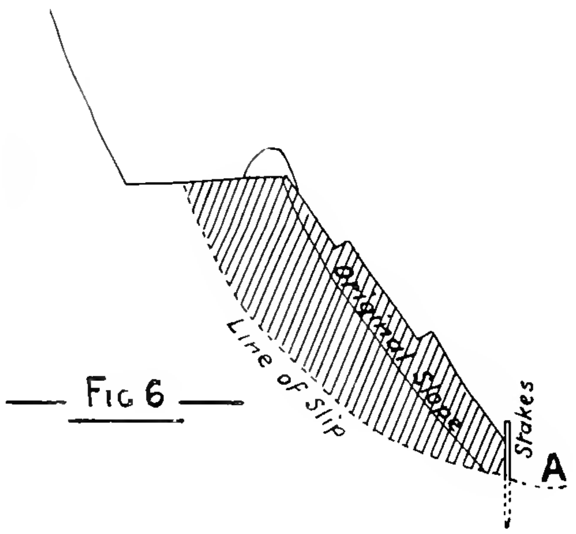

Road Level
Elevation

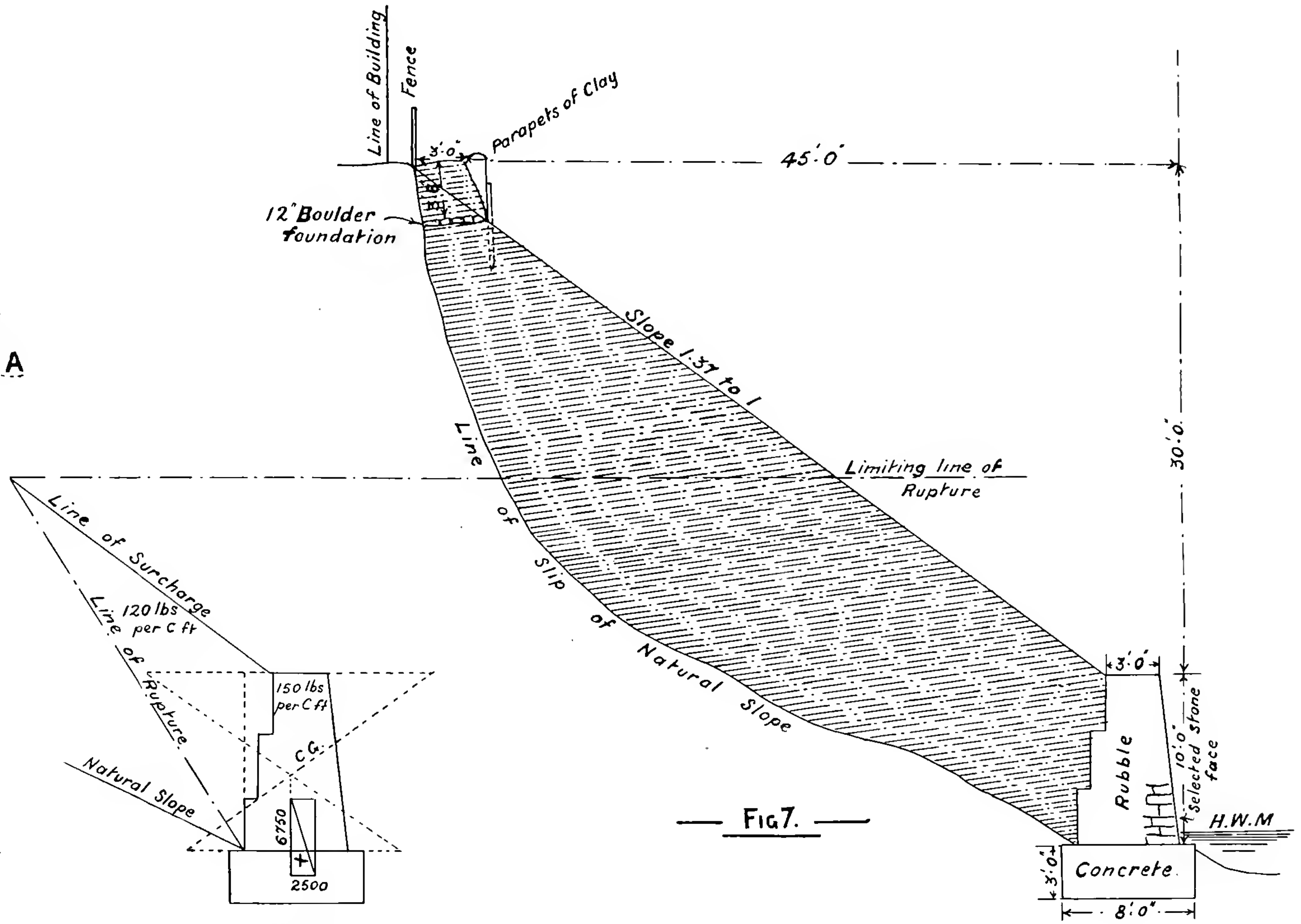
FIG 5

"BRIDLE ROADS" BY H.C. HUGGINS PLATE 2



Original Slope
Line of Slip
Stakes
A

FIG 6



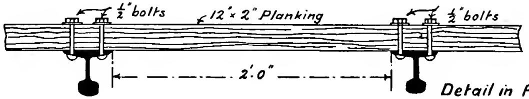
Line of Building
Fence
Parapets of Clay
3'0"
45'0"
12" Boulder foundation
Slope 1.37 to 1
Line of Slip of Natural Slope
Limiting line of Rupture
30'0"
3'0"
Rubble
10'0"
Selected Stone face
H.W.M
Concrete
3'0"
8'0"
Line of Surcharge
120 lbs per C ft
Line of Rupture
150 lbs per C ft
C.G.
Natural Slope
6750
2500

FIG 7.

FIG 8.

12 6 0 1 2 3 4 5 6 7

Scale of Feet


½" bolts
12" x 2" Planking
½" bolts
2'.0"

Detail in Plan

FIG 11

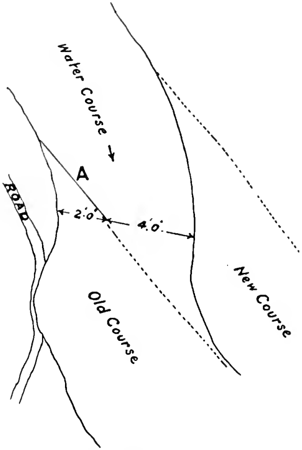

Water Course
A
ROAD
2'.0"
4'.0"
Old Course
New Course

FIG 9

0 5 10 15 20 25 30 35 40 Scale of Feet.

0 ½ 1 2 3 4 5 6 Scale of Inches

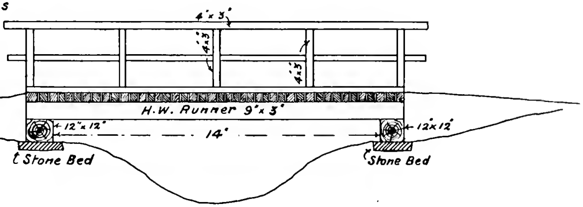
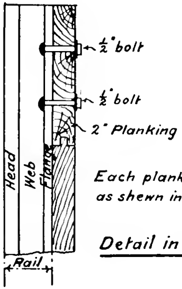

4" x 3"
4x3
4x3
H.W. Runner 9" x 3"
12" x 12"
14'
12 x 12
Stone Bed
Stone Bed

FIG 12

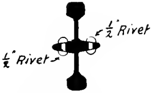
12 9 6 3 0 1 2 3 4 Scale of Feet.


½" bolt
½" bolt
2" Planking
Head
Web
Flange
Rail

Each plank bolted to rail as shewn in top plank

Detail in Section

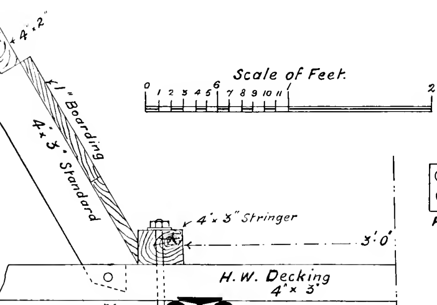
FIG 10



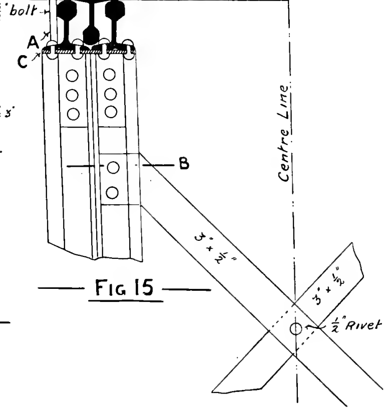
½" Rivet
½" Rivet

Sectional Plan of Pile

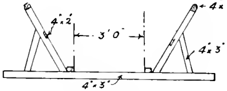
FIG 13



4"×3"
4"×2"
1" Boarding
4"×3" Standard
4"×3" Stringer
3'0"
H.W. Decking 4"×3"
Scale of Feet.
0 1 2 3 4 5 6 7 8 9 10 11 1 2

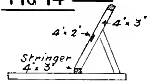


⅜" bolt
A
C
B
Centre Line
3"×½"
3"×½"
½" Rivet



4"×2"
3'0"
4"×3"
4"×3"
4"×3"

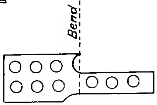
FIG 14



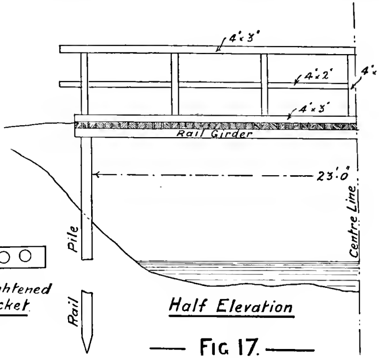
4"×2"
4"×3"
Stringer 4"×3"

FIG 15

FIG 16



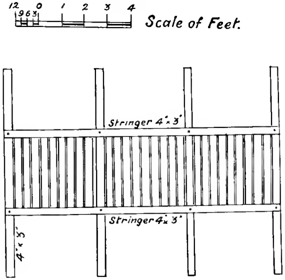
Plan of straightened Angle bracket



4"×3"
4"×2"
4"×3"
4"×3"
Rail Girder
23'0"
Pile
Centre Line
Rail

Half Elevation

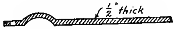
FIG 17.



12 9 6 3 0 1 2 3 4 Scale of Feet.
Stringer 4"×3"
Stringer 4"×3"
4"×3"

Half Plan

FIG 18



Section at B

FIG 19

December 2, 1907.

JOSEPH WILLIAM WILSON, VICE-PRESIDENT,
IN THE CHAIR.

SUBAQUEOUS OPERATIONS INCIDENTAL TO PUBLIC WORKS CONTRACTS.*

By H. BLAKE THOMAS, A.M.I.M.E., A.I.N.A.

INTRODUCTORY.

THE intent of the author of this paper is to lay before the members of this Society a description of practical operations under water with which he has become familiar, knowing full well, that whereas, only a small percentage of members are similarly engaged, yet there are many whose professional duties involve them in the more important sphere of designing submarine structures, and whose opportunities for familiarising themselves with the practices employed under water are small. There will be much omitted from this paper by reason of its limited length. Great difficulty has consequently been experienced by the author in deciding how many subjects to introduce, and at what length to deal with each. If, therefore, the author be accused of being vague, his retort will be that space does not admit of fuller detail.

THE DIVER.

Some people set about the performance of any submarine task by engaging a diver, without asking to see the credentials of the man as a mechanic, and when the work is done, take the man's word as to the result. Whereas, if work of the same importance had to be performed on dry land, the mechanic would be provided with a mate or two, and his work would probably be supervised by the resident engineer and clerk of works, and in some cases by a contractor's foreman and agent. Before sending a man under water to perform any operation, one should tax one's ingenuity to see whether there is no mechanical or other method of carrying out the work from above. In this manner much subsequent anxiety may be avoided, and better and more efficient results achieved. If piles have to be sawn off below low-water mark, do not send a diver down. If holes have to be bored in timber or iron under water, provide the power from above. If submerged rocks require blasting, bore the hole and charge it from above, for the diver is safest away from dynamite. If a rivet has come out of a ship's bottom, do not think a diver is necessary to insert a bolt and nut. Use him when necessary, but as a last resource.

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* A Society's Premium was awarded to the author for this paper.

Subaqueous Surveying.

Before any satisfactory operation can be performed under water, a survey must be made, as is the case on dry land, but whilst on this point let those who hear take warning not to stint the expense of the survey. It must be borne in mind that whereas a land survey, made by an assistant, can be sufficiently checked by his chief in a cursory walk over the site, the case is very different with a submarine survey. What tales could be told by eminent engineers, of difficulties which might have been avoided, and money which might have been saved, had a larger sum been at their disposal for the original survey! A submarine survey cannot be carried out for the same cost as a land survey, for the two do not bear the same proportionate cost to the undertaking, the ratio of the cost of a submarine survey being much higher than that of the land.

In order to carry out a complete submarine survey, a temporary tide-gauge will be the first thing required. This, although simple enough in itself, needs to be made and fixed according to certain recognised rules. Zero on the gauge must be located at a level well below the lowest point that can possibly enter into one's calculations, otherwise where soundings and borings are concerned, minus levels will occur which will be very confusing. This method of fixing a high figure on the gauge has the advantage also of bewildering inquisitive sea-farers, who often learn too much about a scheme before it is propounded. Where a permanent tide-gauge is fixed in a dock or harbour, it is usual for zero to denote the dock sill or the dredged level.

Let the figuring on the gauge conform to the rule given in connection with the draught of ships in the 'Merchant Shipping Act, 1894," which says, "a scale of feet denoting her draught of water shall be marked on each side of her stem, and on her stern post, in Roman capital letters, or in figures not less than 6 inches in length, the lower line of such letters or figures to coincide with the draught line denoted thereby, and those letters or figures must be marked by being cut in and painted white or yellow on a dark ground." Therefore, if any member has committed the error of having a gauge marked after the fashion of a levelling staff, let him rectify his error early, and let his tide-gauge speak the truth to the sailor, who places implicit faith in it, and risks his ship on the strength of it.

This paper cannot pretend to review the different kinds of "soundings" one may be called upon to undertake. Nevertheless let especial reference be made to the importance of not only recording the exact depths of soundings and the level of the water at the moment the sounding is taken, but let the location of the sounding be observed, and booked with the utmost care, for the author does not hesitate to say that, in nine cases out of ten, an error in location causes far more inconvenience than a slight error in the taking of the sounding. Clerical errors both in the sounding and the locating of it are particularly dangerous, being plotted in the office with blissful ignorance, while the subject of the error composedly rests, hidden from the eye, fathoms deep, without a chance of being discovered. To drive this point of accuracy home, let the question be asked, "How often are soundings checked"? Yet when a railway engineer levels, he checks everything before he returns to the office.

Afloat in a high wind and strong current, one may be anxious to sound in the right place, but the difficulty is "to get there." Hence the importance of proper appliances. In deciding upon your method, let provision be made for "loitering" and remaining in any spot you may require. Trailing a graduated rope or wire behind a boat will be futile, as a missed sounding will probably result in your having to start a section afresh. Get the points of sounding fixed if possible, either by cross-sights from the shore, or by a fixed line over the water surface, or by a properly moored raft. The latter cannot be beaten for extreme accuracy.

Avoid recourse to men on shore signalling to you. Get all your sights fitted up before you go afloat, and when afloat be independent of assistance from the shore. Do the whole thing yourself, even to the reading of the gauge if possible, but if not thus able, then take a sufficient number of observations and precautions to avoid an error in reading, or if the error be made, to enable you to discover it.

The most convenient attachment for handling a sounding lead is a flexible steel wire rope, an eighth of an inch in diameter or even more if for sounding with a heavy lead. Gradations may be made every foot by means of leather laces inserted between the strands of the rope, while at every 5 feet a leather tab may be seized on, having a shoe eyelet inserted for every multiple of five. If accuracy in sounding is required to within an inch, a chain is the only solution, the links of which should measure exactly one inch. For sounding in water not exceeding 40 feet deep, and from a raft or barge as advocated, there can be no more expeditious or satisfactory appliance than a pole. This should be of best Oregon pine, in one piece, about 2¼ inches square, planed and painted black and white every 3 inches throughout its length, and figured at every foot, weighted sufficiently at the bottom to overcome flotation, and to facilitate handling in a swift tide. The author has used such poles up to 48 feet in length. They clearly indicate whether or not the sounding is being taken perpendicularly, and readily enable one's sense of touch to judge of irregularities on the bottom.

The sounding machines seen by the author have been extremely ingenious, and have reflected the greatest skill on the part of the inventors. They are adapted for rapid work, and the lead being fitted with a diagonal straining wire, they are capable of being used in a current where a free lead would fail. Their sphere is small, for so few harbours are sufficiently clear of anchors, cables, and boulders, to warrant the use of such delicate instruments. If, however, soundings have to be undertaken on a sufficiently large scale, in water free from all low-lying obstructions, then a sounding machine would undoubtedly be a boon.

Trial Borings.

A more important work cannot be conceived than that of obtaining reliable information as to the nature of the sub-strata prior to an engineering work being commenced. It has fallen to the lot of the author at one time and another to superintend submarine trial borings. Tedious as it may be, standing for hours on the exposed deck of a pontoon or raft, the importance is impressed on one of the necessity of watching the procedure from beginning to end, and thus ensuring that the location, the depths, and the samplings, are accurate, for of what avail is the information unless correct in every detail?

If the ground be soft, a sludge pump may be requisitioned, and an outer tube must be followed down to prevent the sides of the bore-hole falling in, but upon reaching any firm ground in the shape of clay, the use of an outer tube need not as a rule be pursued. If gravel be met, a shell or pod auger should be introduced, and if perchance a large stone be encountered, a worm auger will ofttimes clear the obstacle. When the rock is reached, which we assume is the desired end, it will be necessary to pound away at it with a jumper rod and bit for a sufficiently long time to ensure that it is not merely a boulder. This part of the work must not be hurried, for is it not within the recollection of many, that works designed to be on rock foundations were in fact built upon concrete or piles, on account of the bottom proving to be of boulders instead of rock. If the scheme be large enough, and a few hundred pounds be available, a diamond or other rotary drill may be used to advantage. This will not only expeditiously bore a hole of sufficient depth to test the rock, but will produce a sample core.

Sometimes it may be conjectured that there is no rock in a certain vicinity, and the engineer, before making up his mind that all jetties, walls, etc., must be carried on piles or cylinders, desires to take a few prickings in order to confirm his views. This is a simple enough operation until a depth of 20 feet is reached, but becomes very tedious if pursued to a greater depth by means of manual labour. A rotary power-driven drill with a steel "crown" will be found to be the best implement, and the author has in this way bored to a depth of 100 feet in an hour or two without following down with outer tubes.

Rock Blasting.

The expert miner or quarryman would find most of the methods he adopts on dry land of little or no avail in the blasting of submerged rocks. He must, as a general rule, forfeit his scientific placing and directing of bore-holes, and forget that dynamite and gelignite are expensive, and when he has well nigh filled the bore-hole, let his only regret be that he could not get more into it. Further, he must learn to shatter the rock, for he will receive no thanks from his superior for having blown out stones which vie in size with Cleopatra's Needle.

To substantiate the foregoing statement it should be explained that the submarine miner (not Royal Engineers who are thus termed) should not be consulted as to the placing of the holes. This should be settled in the drawing office, the position of each hole being so carefully tied to landmarks (fixed by a theodolite) that the draughtsman should feel confident he could, if called upon, drop a plumb-bob into the hole after the boring plant had been removed. The spacing and depths of holes, and the size of the charge, can be regulated only by experience, and in reference to the plant that is subsequently to be used in the removal of the blasted rock. In the quarry or mine the cost of the explosive accounts for a large proportion of the total expenditure on the blast, and therefore the strictest economy must be exercised. When under-water work is concerned, however, it is of little account in comparison with the labour expended on the boring. If the rock be blasted in extremely large pieces, there is no mechanical contrivance made which can successfully bring it up from the bottom, whereas if the rock be broken small enough, it may be dredged by the weakest dredger afloat.

The operation of boring should, with but one or two exceptions, be carried on from above the water surface either from a staging or from a floating craft. There are many different forms of drills which may be used, all of which probably hold their own under certain conditions. The old fashioned jumper drill, worked by a number of men pulling down on " tail " or " bell " ropes passing over a sheave, cannot be beaten for simplicity where the work does not warrant an expensive installation, and this system is also the most satisfactory method of boring from craft subjected to heavy rolling.

The diamond boring machine has become well nigh prohibitive for repetition work, owing to the extreme rise in the price of the black diamond.

If working from a fixed staging, or in smooth water from floating craft, the steam or pneumatic percussive drill will be found most serviceable, provided the depth does not exceed, say 40 feet.

The boring should in all cases be carried on through pipes resting on the sea bottom, and coming to the water surface. These pipes are essential for affording lateral support to the drill rod, and as a conduit for placing explosives in the hole.

The explosive should be made up with the electric detonator in a zinc canister resembling an organ pipe, the firing wires passing out through the neck of the canister, which should be sealed, and if possible made water tight. The firing may be effected by means of a series of batteries, or by a rack exploder. If a dynamo be available, the chance of miss-fires will be minimised. A little surplus electricity is desirable to overcome any undiscovered leak in a firing cable, for nothing can be more tantalising, to say nothing of the element of danger, than to feel that the hole is charged and cannot be fired.

Boulder Clay Blasting.

It often becomes necessary to use explosives in the removal of boulder clay when found under water, although it would never enter one's head to blast clay on land. The use of explosives under water is justifiable, first because the clay is more difficult to remove under such conditions, and secondly that the blasting is more efficient by reason of the head of water covering and surrounding the charge.

The author has made an implement which he terms a " clay exploder." This appliance has served him well on many occasions, and has the advantage of being self-contained, and requiring nothing more to operate it than two men with a boat or raft, according to circumstances. The implement consists of a stout drawn steel tube of about 2-inch internal diameter, having the bottom end bevelled to form a cutting edge, the top fitted with a stout screw socket, and about 6 feet down from the top a long slieve shrunk and pinned on to the tube. The whole tube forms as it were a sheath. Into the sheath is fitted another tube, which without any machining should be a fairly good fit throughout, but a snug fit at the bottom. The lower end should project a few inches below the sheath, and be forged solid with a tapered point, while the upper end should be screwed into the head of the sheath, and should have two holes therein, the one for slinging purposes and the other for inserting a bar for unscrewing. There should be also a sliding weight with ropes attached fitted on the sheath between the head and the slieve piece.

The spear is screwed into the sheath, and pitched in the desired position for a blast, the sliding weight or monkey is then operated by means of the bell ropes, and the whole is driven into the clay to a depth, say of 4 feet or 5 feet. The spear is then unscrewed and withdrawn, and the sheath moved to and fro to ensure its easy withdrawal at the required moment. The charge of dynamite enclosed in a canister and with firing wires attached as previously described is lowered down the sheath and forced to the bottom with a wooden ramrod, then without releasing the ramrod, the sheath is carefully withdrawn from the ground and the charge exploded.

It is patent that this method of clay blasting is only suitable in shallow water, but the author has on one occasion bored and blasted with a contrivance as afore-described in 20 feet of water.

The Diving-Bell.

For many years diving-bells have been abandoned, and those in existence have been looked upon as curiosities, and used for no other purpose than for the storage of oil or as a watchman's cabin at the pier head, where the self-same diving-bell has done such Trojan work. This is probably to be accounted for by reason of the great improvements which have taken place in the last thirty or more years in diving-dresses, but times have again changed, and the diving-bell is once more coming into favour, owing to the introduction of electric light and telephones. In olden days, men's lungs became so charged with the carbon emitted from the candles, that the health of the men was seriously impaired.

The author pins his faith to a diving-bell (in preference to divers) wherever it can be introduced, and he must therefore be excused, if he deals at some length with the subject in order to justify his attitude.

There are two kinds of diving-bell generally in use at the present time. One of these is termed the "Caisson Bell," and is an expensive piece of plant on account of its great weight. There are one or two such bells in the British Isles, and the author has spent many hours in one of them.

The bell proper is of steel, cylindrical or rectangular in shape, weighted externally to overcome its displacement. Inside the bell are electric lamps, a telephone, seats, racks, and any special equipment for the particular work it may be engaged upon. From the crown of the bell rises a cylindrical steel shaft of say 30 inches in diameter, surmounted by an air-lock which stands above the water surface. The air supply pipes and electric wires pass down the shaft, and men are able to ascend or descend at pleasure by means of an iron ladder. This bell, which may weigh anything over 50 tons, is suspended from a gantry, or from a specially constructed pontoon, and is capable of being raised or lowered at will. The pontoon is fitted with the necessary boilers, air compressors and receivers, winding engines, mooring winches, etc., and altogether the plant is very elaborate and expensive.

The other kind of bell, which, owing to its simplicity, is more commonly used, may best be termed a "box-bell." It is identical with the oldest bells, save that, perhaps, the shape has been modified somewhat, and that it is now made of mild steel instead of cast iron. The box-bell is rectangular in shape, weighted on the outside, and stands about 6 feet high. If the bell, however, is to work in a trench, or alongside a wall, the ballast will be more advantageously placed inside, but this will curtail the room. The ballast should not, in any case, reach within 4 inches of the bottom of the bell, and, if fitted outside, should be bevelled on its lower and upper edges to avoid catching in any obstruction. For the same reason, all external angles of the bell should be well rounded. There may be two or more plate glass bull's-eyes inserted in the sides similar to ships' portholes. Although these give a better light, if placed near the top, they should, for the safety of the men, be kept down as low as possible in case of breakage. Towards the top of the bell, forged slinging eyes should be fixed, and these, together with the sling chains, should be fully four times as strong as an ordinary crane chain designed to lift the same weight. In the crown of the bell the air supply pipe is fixed with a gun-metal connection and non-return valve, so that in the event of the pipe becoming severed the air shall not escape from the bell. A gun-metal gland makes the necessary water-tight connection in the crown for admitting the specially manufactured cable. This cable carries all the telephone and lighting wires to the surface. Through another gland works a signalling rod, which is found to be very convenient for communication when lowering, raising, or otherwise operating the bell.

An electric, steam, or hand winch is necessary for lifting the bell out of the water, to allow the men to enter and leave, but it is not desirable to sling it from the jib of an ordinary crane without some precaution having been taken to obviate the possibility of the crane slewing rapidly, thus causing the bell to capsize.

The distinct advantage of the diving-bell is that almost any man of ordinary physique is willing to go below in it, which is a decided boon to the engineer and foreman, who are frequently troubled by divers absenting themselves from work through sickness and other causes.

Divers are apt to despise the bell. They seldom volunteer to work in one, and do not hesitate to describe it as a "death-trap." This is not a fair term to use, for accidents to a bell are well nigh impossible, if ordinary precautions are taken. At the worst, a man may dive from the bell and come to the surface without difficulty, and he may rely upon not being short of breath on his upward journey, by reason of the compressed air having fully charged his lungs. Brunel dived out of a bell early last century, and it has been done in the present century to the author's knowledge.

The following are a few of the many submarine operations which are more efficiently performed by means of a diving-bell than by a diver:—

1. The scalping of rock to form foundations, as also the laying and screeding of a concrete bed, on which to set heavy concrete or masonry blocks. The custom of suspending heavy railway metals, and setting a diver to screed in a bed of concrete level with the underside of the rail, is as useless as it is impracticable, for not only will the concrete sent down to the diver be devoid of cement by the time he has trampled and mauled it about, but the screeded bed will be level only by accident. On the other hand, within a bell, the concrete may be spread with care, and levelled with an ordinary straight edge and spirit level. The author goes so far as to say that, in his opinion, engineers should specify in all large works of block-setting, that the screeding be done by means of the diving-bell, for if the first course of blocks be laid out of level, how can it be expected that the second and subsequent courses shall be level? Furthermore,

if the engineer wants a substantial base to his wall or pier, let him pay particular attention to his bottom course. From the contractor's point of view, nothing will ensure such economy in block-setting as a little extra money spent on the reception of the first course.

2. The examination and renewals of roller paths for dock gates is a simple matter when performed from a diving-bell, but the task, if undertaken by a diver, must not only be arduous but unsatisfactory when completed.

3. The cutting of a trench in rock for sewer outfalls, and the grading of concrete to receive the pipes.

4. At Gibraltar, a diving-bell was recently engaged in sinking pits and trenches for burying permanent mooring chains and anchors, in order that there should be no projection above the sea-bottom which might prove a menace to shipping.

Concrete.

The author prefers, in a paper of this sort, not to dwell upon the science of mixing and making concrete for "in situ" work under water. He will, therefore, restrict his remarks to one or two details concerning the casing or shuttering used for submarine structures, and the mode of lowering the concrete.

Casing.—All are familiar with the method of sliding panels in grooves or channel irons. This method, however, cannot well be adopted under water, inasmuch as the raising of the panel cannot be effected until the concrete has set, and who is there, who would dare to strike under-water casing in less than a fortnight from the time the concrete was laid. Consequently, this method becomes impracticable, as the work cannot as a rule be left for so long a period.

The method handed down to the author by his predecessors, has been to commence the casing at the bottom, and never to strike a board until the concrete in that particular section has been brought above low water-mark. No other method can ensure a successful facing to the concrete, and it is by far the cheapest, because the price of planking is insignificant compared with the divers' labour necessary for releasing and adjusting panels.

The planking used is, generally speaking, 3 inches thick by 9 inches to 12 inches wide, tongued and grooved, with the tongues $\frac{1}{2}$ inch thick, but with rather more clearance in the groove than is given in dry land work. Sometimes circumstances warrant the making of panels of say 4 or 5 boards width, in which case it will be seen at a glance that a considerable amount of ballast is necessary to sink the wood. This coupled with the cumbersomeness of the panel itself often entails the use of two divers. It will be found preferable and more economical in most cases to fix the casing in single boards, having the spike holes bored in the ends ready for the diver to drive the spikes.

For this fixing of the casing the author has found that a weighted stirrup iron fixed on either end of the plank is the most satisfactory, for it has the treble advantage of being the means of fixing the rope, of sinking the board, and of guiding and holding it in place at one end while the single diver walks to the other. Two men at the surface throw the planks overboard with the sinkers attached, and lower them into position for the diver, who remains below and fixes the boards very rapidly. A thumb-screw releases the sinkers, and they are hauled to the top.

Tipping Boxes.—Concrete should be lowered through tipping boxes having doors in the bottom, and although for "hearting" work the doors may be hinged on both sides, for face work, a box with a single door should be used, having the hinges on the side remote from the casing, which causes all the concrete to press against the casing upon the catch being released. Catches should be automatic in their action, so that the diver shall not have a hand in the matter. This will obviate injurious results both to the concrete and the diver's hands.

It is not implied that the services of a diver are always necessary, for in "hearting work" there is no need for one; but for "facing" it would be folly to do without one, until the work has reached within a few feet of low water-mark. The larger the box the more efficient the concrete, and on no account should the concrete be moved after it has fallen from the box.

THE SUBMARINE TELESCOPE.

This is a most useful invention to have about a dock or on board ship, and is wonderfully efficient in depths not exceeding 10 feet. It is very useful for examining a ship's propellers, and for many other services.

DREDGING.

This heading comprises so much, that no paper dealing with submarine operations would be complete without making reference to it. Being so wide a subject in itself, it will be impossible to do more than to pass a few general remarks upon different methods employed.

Bag and Spoon.—It would appear that this is one of the earliest forms of dredging, but because simple and antiquated it must not be condemned, for there are cases where this becomes the cheapest method. To give an instance, the author recently had occasion to remove a small quantity of gravel from a corner inaccessible even to a grab barge, therefore a bag and spoon came as a boon, and in a day or two removed the obstacle.

The American Dipper Dredger.—The author has had no experience of this machine, but it appears to have been evolved from the "bag and spoon," even if the steam navvy has been one of the stages in that evolution.

The Grab Dredger.—Although despised by many who are engaged on extensive dredging work (owing to its comparative slowness), the grab dredger still continues to hold its own in certain dredging works, such as the clearing of isolated patches and awkward corners, as also the maintaining of small fairways, harbours, and basins, where the cost of a bucket or suction dredger would be prohibitive.

Grabs may be divided into two classes, viz. single-chain grabs and double-chain grabs, the former capable of being used with an ordinary crane, and the latter involving a special crane with two barrels.

There is no intention of advertising any firm, but it is essential to mention the names of the makers when describing grabs. Messrs. Priestman Bros., of Hull, undoubtedly produce one of the best double-chain grabs. Their cranes are also of excellent make, but they do not stand alone, as there are other makers who follow almost identical principles in the construction of the grab, and are no doubt, therefore, very keen competitors of the firm named.

The single-chain grab which appears to be most in use is Hone's grab, made by the Thames Ironworks Company. Other single-chain grabs no doubt give satisfaction, but the author prefers the Hone's, which, with a few slight alterations, are easily adapted for under-water work.

It is often argued that grabs will not work in blasted rock, and although the author has removed many thousands of cubic yards in this way, he has been told emphatically by the inventor of a grab, that no grab, either single or double, could work satisfactorily in rock. It is true that many single-chain grabs are utterly useless for such work, but Priestman's, and Hone's, double and single chain grabs respectively will do good work, if well stiffened, and if manipulated scientifically by the crane driver.

The Bucket Dredger is undoubtedly the most serviceable tool for all round work, for not only can large quantities of dredging be dealt with by means of it, but in the event of the material changing from soft silt to fine sand or gravel, or clay or rock, the bucket dredger will still answer with varying degrees of success. Bucket dredgers may be divided into three classes, viz. stationary, self-propelling, and hopper.

Stationary dredgers are the oldest form, and even now in certain cases are all that is required, if they are not to be moved from port to port. Some stationary dredgers which are now in use are getting very old, but the strength with which they were built, and the good machinery which was put into them, make them still very serviceable.

Self-propelling dredgers are extremely useful for moving about from port to port, and even for working in or about large harbours, where the inconvenience of towing them becomes a consideration.

Hopper dredgers, which are self-propelling, will be found economical and satisfactory in narrow waters, where the mooring of a stationary dredger with hoppers alongside would be a hindrance. They are also most useful in removing rock, where the cargo takes some time to obtain, and where the time occupied in discharging the cargo is insignificant in comparison with the time taken in getting it.

Suction Dredgers have easily beaten all records, but although they can dredge such surprising quantities of sand, yet their sphere is very limited, and when put to work in gravel, it is nothing uncommon for their output to be reduced by 50 per cent. When made to work where clay or large stones prevail, they immediately fall far short of the bucket dredger. It is a fact that a sand pump can pass almost anything which enters its suction pipe, but let not this statement be taken to mean that it is good for the pump. On the contrary, the passing of large stones causes excessive wear, and breakdowns at times not expected. The conspicuous advantage of a suction dredger over a bucket dredger in the removal of fine sand lies, not only in the fact that the output of the suction dredger in such material is greater than that of the bucket dredger in any material, but that the bucket dredger works remarkably badly in fine sand, inasmuch as the buckets can only be filled flush, and the sand becomes so consolidated that it will not leave the bucket at the right moment, a large proportion of it returning to the bottom.

DREDGERS FOR RECLAMATION WORK.

The low-lying lands in Holland afford an excellent opportunity for land reclamation, owing to the difficulty of finding a "dumping ground" for the immense amount of dredging that is carried on in cutting and deepening the canals, and by reason of the greatly enhanced value of the land when thus raised a few feet. Nature seems to have been kind to the Dutch in that there is an absence of rock, and that the dredged material is such that it can be almost invariably put into solution or suspension.

The prevalent custom in Holland is to use a bucket dredger to excavate the spoil, and a suction dredger to unload the barges, and to deliver the material on to the land.

There is in the North of Germany and Denmark a method which seems to commend itself for "reclamation" work, as it is adapted for work in material which may contain a certain proportion of stone, gravel, and clay. This method consists of a bucket dredger with a special ladder over the side which exactly fits the well of a barge, and no matter how stiff the material is, it can be dug out of the barge. It is then elevated a considerable height and, by means of a powerful centrifugal pump, washed through pipes leading ashore.

The author has been recently engaged upon the reclamation of about 40 acres of land from the sea, and the raising of it to a height of 6 feet above high water-mark. In the execution of this, a plan has been adopted which, as far as his knowledge goes, has never been used in its entirety in this country before. This statement is made not in any boastful spirit, but rather with the intention of drawing some one to give information of a parallel case.

The dredging and reclamation, to the extent of over a quarter of a million cubic yards, was carried out by one suction dredger, which not only moved about and cleared the ground to a given level, pumping the spoil (mostly sand and gravel) ashore through a floating tail of pipes ($\frac{1}{4}$ mile in length), but when working at low tide elevated the material 17 feet and pumped it through a considerable length of pipe on the shore. These shore pipes were necessary, owing to the spoil being too heavy to flow in solution, and the consequent accumulation of big heaps of stone at the pipe end, which no ordinary force of water could disseminate.

The wear and tear in the pump was very great indeed, but this is no argument against the scheme. The fact remains that no other known method could have been applied so cheaply.

The longest length of pipe used collectively, afloat and ashore, was two-thirds of a mile, but under certain conditions, there is no reason why a mile of piping should not be used.

DISCUSSION.

The CHAIRMAN said that the subject was a very wide one, but the author had managed, in the course of three-quarters of an hour, to bring before the meeting many important details well concentrated. He had very rightly emphasized the fact that engineers should do without divers if they could, and though they were very necessary under certain circumstances, they were not a cheap article at the best of times. There could be no doubt as to the importance of every engineer being able to assume, if necessary, the diving dress for the purpose of inspecting works under water. Only the other day an engineer told him that he had some divers at work in underpinning the toe of a concrete breakwater, and they were supposed to be digging out an excavation to certain dimensions, and filling it up with a special arrangement of concrete; but he had to take their word as to its being properly done, and, though not a very sceptical man, he would have liked very much to go down and see the work himself. As to the diving bell, it was, as they knew, a much simpler affair. It was pleasantly supposed that the man who went down in a diving bell did not require any skill whatever, and that, therefore, he need not be paid at any higher rate than other workmen. He remembered that when the members of the Society visited Folkestone Harbour works at the time that they were being extended some years ago, they were told that the men in the bell were not paid more than ordinary wages. It was clear that there were different amounts of skill required for working in a box bell and in a diving dress; the latter obviously requiring a good deal of practice in manipulation. The author had suggested that until very recently the diving bell was out of fashion. That might be to a certain extent true, but bells had been used for many years. They were aware that at Dover the Admiralty work had been done very much with bells, which had been used for preparing the bottom for the blocks that had been put in. Dover was, he thought, a good example of the combination of the box bell and the diving dress. After the bells had been used in preparing the bottom, the blocks were lowered separately, and divers went down to see that they were placed properly *in situ*. He did not see why a diver should call the diving bell a death-trap. It had always seemed to him that a diving dress might be called a death-trap, and as many risks were as likely to befall a man in a diving dress as a man in a bell. He agreed with the author in thinking that, when the bell was properly manipulated, it was a very safe thing. At the same time, if the bell rested on the bottom and anything went wrong, it was not possible for the man to dive out of it. He would ask the meeting to give a vote of thanks to the author, and he was sure that they would do so very heartily.

A vote of thanks was then accorded to the author by acclamation.

Mr. F. G. **Bloyd** said that the subject brought forward by Mr. Blake Thomas was one of great interest. The keynote of the paper was, he thought, contained in the first few words under the heading "Subaqueous Surveying," in which the author said, "Let those who hear take warning not to stint the expense of the survey." Perhaps more trouble had been caused by surveys below water having been stinted in the matter of cost than had been the case in any other preliminary engineering operation. The author had pointed out that it was impossible, without a proper survey, either to gauge the extent of the bottom or the evenness or the unevenness of the surface, or the probable extent to which foundations would have to be taken. He agreed that spending money in the first place on a survey might often save considerable expenditure afterwards.

With regard to the question of soundings, the author said that in order to carry out a complete submarine survey a temporary tide-gauge would be the first thing required. This was another very important item. He could speak with a little experience as to some soundings which the railway company with which he was engaged had to take periodically near the mouth of the Medway in providing a channel for Continental steamers. The depth was never very good, and, although the steamers drew only 12 feet of water, a difficulty was found in maintaining a depth of 14 feet of water at low tide. A bar formed at the mouth of the river, and although they had a tide-gauge at the pier where the steamers were berthed, yet this pier was situated at some distance from the portion of the channel where the siltage occurred, and the first step always taken before any soundings were taken, as they did every two or three years, was to fix up a temporary tide-gauge as recommended by the author. The tide-gauge was placed in full sight of the man who was taking the soundings, and therefore he could first take the soundings from a boat and book them, at the same time noticing the exact state of the tide. This was a very important point, and conduced greatly to accurate information being obtained. The soundings had to be taken over an area of about 1000 feet long and 300 feet wide, and their plan was to have two boats moored one behind the other. They took their centre or base line from a leading light on the pier in front and a large tower on the mainland behind. These two fixed points gave a good and convenient line, on which the whole plan of the soundings was built up. That was a very great advantage, as it enabled the soundings to be taken each time on the same spots, and recorded on a large scale chart in the head office, the soundings being plotted thereon in different colours from year to year as they were taken.

Accuracy in taking soundings enabled a very good estimate to be formed of the cost of the dredging that would have to be carried out. If an engineer could give his board of directors or his harbour or port trust a good estimate of the number of cubic feet which would have to be dredged, the contractor would give a much closer price than he otherwise would.

Referring to the question of dredging, the author said that the grab dredger was of exceeding use in awkward corners and inaccessible places. There again he (Mr. Bloyd) thoroughly agreed with the author. His company had several small docks and harbours which had to be kept free of mud, and one course which they had followed was to erect a grab worked by hand power on a small harbour barge. The barge could work all round a harbour or dock without disturbing the rest of the vessels, and it could pick up the mud under the quay walls where it mostly silted up. The work could be done very much better by this means than if they employed a large dredger. A dredger was once taken into one of the small harbours, but it so dislocated the traffic that they had to keep boats outside, and steamers which made periodical calls lost a few tides by having to wait. The small grab dredger to which he had referred was found to work very cheaply.

In connection with the question of rock dredging, the author alluded to blasting to get rid of rock, but he would like to ask the author whether he had any experience in removing rock by the rock-cutting ram. That system was used, he believed with great success, in the widening of the Suez Canal some years ago. The ram consisted of a sort of iron pile, with a cutting edge which was dropped upon the rock and shattered it into pieces; and it was stated that they could get a more even bottom in the bed of the canal by this means than they could by blasting. In blasting, more rock might be removed in certain cases than with the ram, but more even work was claimed to be accomplished by the latter. He should like to know whether the author could say anything more on that point.

In speaking of the diving bell, the author had referred to the portholes, and had recommended that they should be put low down to avoid breakage. He thought that the author would admit that the portholes of a diving-bell were protected by bars inside and outside, so as to minimise the risk of breakages as much as possible.

The paper had dealt, perhaps, more with the preliminary part of subaqueous work, and it had not made any allusion to preparing foundations for sea-work by putting concrete bags *in situ*. He believed that when the South Pier at Aberdeen Harbour was extended some years ago, the rock on which it was formed was exceedingly hard granite, and it was recognised that it would be a very expensive work to remove it, either by blasting or by any other process. Therefore a layer of concrete bags was tipped on the top of the granite, so as to make the surface comparatively level; and then divers filled in whatever small holes there might have been with very small concrete bags, so that they got a good bed on which to rear the structure of the walls.

Dredging, and the filling up and reclamation of ground by the suction dredger, were points which were being widely followed. He could call to mind several low-lying tracks on the Medway which had been successfully filled up with a pump dredger. It elevated the silt directly over the low retaining walls, and very good pasture land now existed in many places which were waste land previously.

He agreed with the recommendation of the Chairman that every engineer should, if possible, become a diver. He remembered in a paper which they had heard from Mr. Latham, of Penzance, a few years ago, the same remark was made; and what was, perhaps, more important was that Mr. Latham told them that he always went down himself to see every piece of work before he passed it. The author's paper had shown that more engineers ought to take up the study of diving, and nowadays it was possible to take practical lessons at no very great expense.

Mr. E. J. SILCOCK said that they were much indebted to the author for an exceedingly able and interesting paper. He had not himself had much experience of diving bells, although he had seen them in use in various places, among which were the Dover works which had been already mentioned, and he must say he thought that, for the preparation of ground for the foundations of walls, diving bells had very distinct advantages over divers. He had a very great admiration for divers as a class, but they had their peculiarities, and one of these was that they were not always to be depended upon at the particular time that they were wanted. Their work was of a very precarious nature, and it often occurred that at a particular moment they were unable to do the work which they were required to do. A diver could go to very many places in which a diving bell would be of very little use. He once had to remove the wreck of a large steamer which was broken in two, and he had to put a bulkhead in the open ends and float the vessel away. She was filled with silt and sand, and the divers had to fit the bulkhead under water, and the silt and the sand had to be removed from the hold of the vessel. This was done by pumping the silt out through a flexible suction pipe. There was a little point of detail which might be of interest, and that was he found he could remove the sludge and mud very much more easily with the pump when he had contracted the nozzle on the suction pipe end. When the pump was working with the ordinary full bore suction, there was not half as much stuff removed as there was when a conical end was put on which contracted the end of the suction pipe to about a quarter of the sectional area of the pipe.

Divers were often used for examining dock gates and moorings and things of that kind in which it was obvious that the diving bell could not be used.

The question of dredging was a very large one, and one on which they might easily have a long discussion. The Dutch were alluded to by the author, and with reference to them he might say that he was very much struck some few years ago by the fact that the Dutch could build a dredger for less money than Englishmen could. He had to buy a dredger in a hurry, and could not find one in England as cheap and good as one which he bought in Holland. He was struck with the fact that the engines of the Dutch dredgers were, for the most part, made in England, but the hulls and gearing were made in Holland. Dutch dredgers were mostly designed for work in their own country, and they were not, perhaps, so strong as the dredgers in use in England, and one would not care about using a Dutch dredger to dredge rock with. They were made for dredging soft material. It always seemed to him that the hopper dredger was a mistake. He did not know what excuse there could be for building a very large machine which had a large ladder and buckets, and the necessary machinery for dredging, and then to use it for conveying the material dredged. It was far better to have the dredger as a separate machine, and to let the dredgings be put upon hopper barges towed in the ordinary way, or propelled by their own machinery. Certainly, he did not think that the dredger itself should be connected with the hopper. They would have a great deal of dead weight to lift about the country for nothing, and the dredging work would be stopped while the hopper was being discharged.

There was one type of dredger which he should like to mention as it was not mentioned in the paper; that was the dredger on the "Eroder" principle, which, he believed, had not been very largely used. The principle of it was to utilise the power of water to transport the material, rather than to lift the material actually clear of the water and pump it on the land. This dredger consisted of a vessel which was fitted with a vertical shaft carrying on its lower end some sort of tool varying in design for the work which it had to do. This was revolved near the bottom, not actually in the mud, but near the soft material. It created a swirl in the water, the material was churned into suspension, and was carried away by the current. Mr. Wheeler of Boston, who was a well-known authority on all matters connected with rivers, was the man who suggested the idea, and he possessed a machine on that principle which was working in the river at Boston, and very successful results were obtained with it. They were able to shift soft material in the river at very low cost indeed. He (Mr. Silcock) had had a machine working on the same principle, but he must say that it had not been quite so successful. There must, of course, be the proper conditions; that is to say, the material to be removed must be soft, and there must be a strong current. Without those two conditions, the machine was not applicable.

Mr. R. J. Bevil Sharpe said that the paper had been most interesting to him, as he was engaged in the kind of work with which it dealt. He did not quite agree with the author's recommendation, that, in sounding, they should use a long pole. He had always found the use of a pole in sounding in very deep water very slow work indeed. He had found a very light chain to be the best thing for sounding in very deep water. In shallow water a pole might be used. Perhaps he might be allowed to allude to the rock-breaking tools which were mentioned by the gentleman who opened the discussion. That speaker alluded to a machine called "The Lobnitz," which was used on the Tranmere development works, but he did not know if it was successful there. The rock was sandy or something of that character.

The author remarked that no one ever used explosives for blasting clay, but he (the speaker) had often used explosives for blasting hard clay, and it was a common occurrence.

The author mentioned the use of the dipper dredger in America. He (Mr. Sharpe) had seen dredgers of that kind working in America. They were similar to the ordinary steam navvy, but built on a large raft, or on a large flat barge-shaped vessel. There was one working now on Lake Superior. The bucket capacity was 8½ cubic yards, and it would dredge to a depth of 23 feet, and lift 480 cubic yards of sand an hour. He believed that they had never had a dredger like that in England. There was another with buckets of 2½ cubic yards capacity working in stiff clay on the Massena canal. In a day of ten hours it would lift 720 cubic yards working in 20 feet of water.

As to the grab dredger, he thought, as an engineer for harbour and dock works, that that appliance was one of the most useful tools they had. On a river in Lancashire, he had had four working, and he did not know what they would have done without them. They were worked in a place where a suction dredger could not be used. He had found that the Price and Manisty grab was quite as good as the single chain Hone grab. In fact, in his opinion, it was better. He had worked both and had had seven or eight working at a time.

A previous speaker had mentioned Dutch dredgers. He (Mr. Sharpe) had had two working for eighteen months, but he had found them a great deal too light for the work which generally had to be done in England. They were built in Holland for very light work, and, as a rule, they would not last more than half the time of those dredgers which were built in this country. He had found that a Dutchman could get about 25 per cent. more work out of them than an Englishman. He did not know why this was, whether it was that the Dutch understood the work better, or that they were steadier men. As a fact they were steadier.

One failing in English dredgers to-day was, he thought, that the buckets were too small. Mr. Newell had moved in the right direction at Hartlepool, and had made an enormous dredger about three times the size of any other dredger that he (Mr. Sharpe) had seen.

He thought that the suction dredger would become more general in England every day. He had had a lot of experience with suction dredgers, and he had used them in gravel as well as in sand, but he did not find that the output was reduced nearly as much as the author had said, namely, 50 per cent. He (Mr. Sharpe) had found that in ordinary loose gravel, it was not more than 25 per cent. He thought that suction dredgers were most useful tools for reclamation. There were now several working at a large dock which had been built on the Humber, and they pumped stiff clay from lighters. Bucket dredgers dredged the clay into the barges, and the suction dredgers pumped it ashore from the barges. He forgot the exact distance that it travelled, but it was nearly a quarter of a mile, going in a similar way to that which the author mentioned. He had himself used a suction dredger for pumping silt and gravel ashore from barges over the same kind of ground that was alluded to just now, on the Medway. In fact, he thought that the ground mentioned was the same he had reclaimed near Rochester. It was a swamp, and could not be walked upon. He had not seen it for some years, but he believed that it was now good sound ground.

The author mentioned that he had reclaimed land from sea by pumping ashore direct from the dredger. That plan was adopted at Preston on the Ribble some eight years ago, but it was abandoned for a reason which he had forgotten. He believed, however, that it was in use at the present time. They were doing exactly similarly to what the author mentioned. There was a suction dredger, and it was delivering ashore through a long system of pipes filling up the old Ribble behind the floating dock.

He (Mr. Sharpe) had heard on good authority that this work done by the Lobnitz at Tranmere was quite successful.

Mr. Maurice Wilson wished to add his word of thanks to the author. He always liked a paper which was a little bit out of the common way. He agreed with what had been said as to the importance of an engineer being able to go down under water to inspect work. He presumed that the author was in the habit of so doing, and it would be interesting to have a few details as to how he ascertained whether the men in the diving bells were doing their duty. He (Mr. Wilson) remembered his father stating years ago that when he had pier work to do with the diving bells, he used to go down, if he suspected the men were not doing their duty. On one occasion, there being only one bell available, he inspected it during the dinner hour, and found a large crab in the bell with the name of a horse that was to run for the Derby, chalked on its back. This accounted for the rapidity with which the men had got through their work!

In connection with the rock blasting, it would be interesting if the author would mention the explosives that he usually employed. Dynamite was mentioned in one case, but he (Mr. Wilson) did not gather that it was the one the author mostly used. About twenty years ago he had to do with an excavator which was being used in the construction of the Manchester Ship Canal. The engineers got into great difficulties on one of their cuttings about twenty miles away from the sea. When they had removed some fifteen or twenty feet of material with the steam navvies, they found quicksand, and this bothered them exceedingly. He was not sure whether they did not lose two or three of the steam navvies in the sands. In the end they let the water into the cutting, and then partly dredged out the sand from the bottom of the canal, and from the sides, they used a machine which came from Germany. He did not know the proper name of this machine, but they called it the "Lubecker" because it came from Lubeck in Germany. This was a rather ingenious machine. It ran on three rails, and, of course, it could be used only where there was a pretty solid foundation. It was covered with corrugated iron and looked rather like a house. It had a window and a chimney, there was a chain of dredging buckets at the side, and a gap in the middle of it, so that when the tip wagons were filled they were brought up underneath the "Lubecker," and, when the machine started and the buckets worked, the whole "Lubecker" worked itself very slowly along the three lines, and all the sand was scooped up and dropped into a sort of hopper with a double bottom. The bottom could be turned one way or the other, so that when the machine had worked itself along to the end of a tip waggon to avoid the sand being dropped on the ground, a handle was turned, and the bottom moved, and the sand dropped down the other way. They tried two or three other machines, but it was the German machine that was considered most satisfactory and did most work. He did not know whether the author had come across such a machine in which they could work from above the ground in that way.

Mr. R. J. **Bevil Sharpe** said that the machine which had been alluded to by Mr. Wilson did a considerable part of the excavation in one of the docks in Liverpool. He saw the machine working there, and he might say that it was still called the "Lübecker."

Mr. T. L. **Matthews** said that there were one or two points in the paper which were rather interesting from a practical point of view, and on which he would like to pass a few remarks.

To begin with, the author, speaking of under-water surveying, said that zero for soundings should be fixed well below the lowest point that could possibly enter one's calculations, as otherwise minus levels would occur which would lead to confusion, but it was difficult to understand what value could be attached to such an artificial datum.

The ultimate reason for which soundings were taken was to enable plans or charts to be prepared for use by those in charge of ships, so that they might know the depth of water available, and obviously the only useful datum to which such soundings could be referred was that of the lowest ordinary condition of the tide, or low water ordinary spring tides.

If any other datum, such as that suggested by the author, were used for the taking of soundings, it followed that, to be useful, they must afterwards be converted to the L.W.O.S.T. datum, the additional work involved, if the soundings covered a large area, being correspondingly heavy.

As to "doing the whole thing yourself," even to the reading of the tide-gauge, as advocated by the author, this was of course quite impossible when the lines to be taken were of any considerable length. With regard to the tide-gauge, it was very important, particularly in places where the rise of tide is very quick, to plot the readings on "squared paper," and, by taking the heights from the resulting curve, to eliminate small errors in reading.

The author referred to diving bells as being much more satisfactory since the introduction of the electric light and telephone. That was certainly the case as far as electric light was concerned, but with the telephone much more trouble was experienced, the dampness associated with the bells being very bad for insulation.

Telephones had been tried with poor success on the harbour works at Folkestone and Dover, and he (Mr. Matthews) thought it would be interesting if the author could give the name of the maker of the instrument which he had found satisfactory.

The CHAIRMAN asked the speaker whether he had tried speaking tubes.

Mr. MATTHEWS, continuing, said that he did not think these were satisfactory, as the sound of the air entering the bell from the compressors overcame the small sound of the voice, especially in a depth of 60 or 70 feet, where the length of the voice pipe would be necessarily great.

With reference to the author's objection to slinging bells from the jib of a crane owing to the possibility of the bell being capsized by a rapid slewing of the machine, it might be of interest to mention that there had been several 20-ton bells, so hung, in use on the works at Dover for some years without accident, and provided that the bell was properly hung and weighted, there did not appear to be any great risk of such accidents.

The author mentioned that some divers described the diving bell as a "death-trap," but he (Mr. Matthews) had never heard it so called, and quite agreed with the author that the description was not warranted.

Diving out of a bell, however, in case of accident was not quite so harmless as would appear from the paper. Although it might have been done in a few cases in shallow water, it could not be recommended for deep work, where the sudden change from a gross pressure of say 40 or 50 lb. per square inch to the atmospheric would certainly knock a man all to pieces internally.

Speaking of diving generally, he quite agreed with the author that it was most important that engineers should dive themselves, and those who did not do so, certainly did not deserve to have important works entrusted to them.

With reference to the submarine telescope spoken of by the author, he (Mr. Matthews) knew of a case where it had been successfully used in a depth of 25 feet of water.

Mr. A. S. E. Ackermann said that Mr. Silcock had mentioned that he found the suction dredger worked very much better when the area of the nozzle was reduced to about one quarter the area of the suction pipe. He (Mr. Ackermann) thought the explanation of the fact was that the velocity of the water was thereby multiplied by four. The amount of matter which a current of water would keep in suspension depended upon the velocity of the current, and in this case the velocity would be four times. It was very much for the same reason that the exhaust-pipe in a locomotive was throttled.

Mr. H. Blake Thomas, in reply, said that he was glad to note that several speakers, including the President, had confirmed his idea that engineers should, if possible, dive themselves and take all precautions that the divers were going on as represented. Mention had been made of the wages paid to the men working in a diving-bell. He might mention that in a town where the price of labour was 5*d.* an hour, he, on his own initiative, introduced the rate of 8*d.* an hour for men working in a box-bell, and he found that it answered very well. He admitted that he had very great difficulty in getting men to go into the bell for the first time, but when once they had begun upon it they stuck regularly to the work and were very much afraid lest they should lose it. Plymouth was the place to which he referred.

When he made the statement in his paper that bells were coming into fashion again, he meant to include the last few years. He was aware that they had been used in Dover. He might be wrong, but he believed that when he started work of this kind upon leaving school fifteen years ago, there were very few diving-bells in use in England. He believed they came in again about eight years ago, and from that time they had gradually come more into favour. Dover had, perhaps taken the lead, and he felt sure when he put down a box-bell in Plymouth about four years ago that it was the first time a bell of that kind had been under water in that large naval port for ten years, with the exception of the large caisson-bell which he had shown on the screen.

Reference had been made by Mr. Bloyd to the "Lobnitz" machine on the Suez Canal. Of course Mr. Bloyd was aware that the "Lobnitz" breaker referred simply to the breaking up of rock, and not to the picking up of it. He was looking out for the opportunity of using one himself, and he was very anxious to get the experience. No doubt it had been very successful in certain cases. These machines were successful on the Suez and the Manchester Ship Canals, and they had been recommended for use on the Panama Canal. His idea was that the Lobnitz machine was of no use for anything harder than brittle sandstone. He would be very sorry to think that rocks could not be levelled as well by blasting as by the Lobnitz machine.

It was true as Mr. Bloyd had said, that the portholes of a diving bell were protected by a grid, but still he preferred that they should be kept as low down in the bell as practicable.

Mr. Bloyd had mentioned the use of concrete bags for levelling hard rock surfaces in Aberdeen, but he took it that Mr. Bloyd was not referring to ordinary small bags of concrete but to a system of concrete bag-work carried out in an elaborate way. He (Mr. Thomas) had seen heavy bag-work performed, each bag containing a yard and a half of concrete. The bags were rectangular in shape and were placed in a large iron skip. The bag exactly fitted the skip, and when filled with concrete the top of the bag was quickly switched on, the skip lowered to the bottom, and the catch being released the bag took its own seating on the inequalities of the rock. Still there was a difficulty. The question was how to screw off the top of the bags, and, therefore, he still suggested the diving-bell was necessary to form a good *in situ* bed for receiving the bottom course of blocks.

Mr. Silcock referred to reducing the size of the suction pipe, and Mr. Ackermann had dealt with the same point. He (Mr. Thomas) quite agreed with what Mr. Ackermann had said. Mr. Silcock probably referred to a pump which would have a suction pipe about 8 or 10 inches diameter or less. A pump of that size for sand was, of course, very inefficient, and was probably an ordinary salvage pump. One must know that sand could be removed in small quantities with a 4-inch pump or even smaller. It would be unnecessary to reduce the size of the suction pipe when dealing with large suction dredgers.

Mr. Silcock had referred to hopper dredgers. He (Mr. Thomas) might be very bold about this subject, because he had had a lot of experience with hopper dredgers. The hopper bucket dredger was a very extravagant thing to use on large mud dredging works, but it was used to very great advantage where the cargo took a long time to get. Sometimes a waterway was narrow where there was a lot of traffic, or in a dock basin it very often became necessary to use a hopper dredger. There were cases where the hopper bucket dredger was miles ahead of anything else.

As to the river at Boston, he should call the thing that had been described, an agitator, not a dredger. It seemed to him a very lazy kind of machine, which only half did its work. He should like to get some work where the tide would carry the spoil away. It seemed to him like a man sweeping up a street and leaving the sweepings on the side of the street. He should prefer to take the sand away. He could imagine that the agitator would clear the place, but the sand must go somewhere. It probably did go away with the current, but he should be inclined to think that it would come back again at some time. There might be cases where it would pay to adopt that plan, and it appeared to him that it was simply a matter of *l. s. d.*

He quite agreed with Mr. Sharpe that a light chain was very handy in smooth or still water where there was no current, but he should be very loath to use a chain or a lead where there was a strong current. He had used a pole in a 3½-knot current. A pole was the most simple method of getting a vertical sounding, and, of course, a sounding was of no use unless it was vertical. In a swift current it was impossible to get a chain or lead to reach the bottom.

He certainly had not come across any case of blasting clay on land. If clay on land had been blasted, he must admit that his statement was too bold, but the fact had not come within his range.

He believed that the makers of hopper dredgers nowadays laid down the rule that every hopper dredger should load itself in one hour. Most of the hopper dredgers that he had been connected with loaded themselves in an hour. The Brancker at Liverpool loaded 3000 tons of sand an hour.

He should put Price and Manisty's grab next to Hone's, but his objection to Price and Manisty's grab was that when it landed on very unequal rock and fell over, it failed to dig anything without being picked up again. The Hone grab was the only single chain grab which he had found which would automatically catch itself when it was lying over at a certain angle.

His experience of Dutch crews was that they were very much better than English, and without disrespect to the Dutch he would say that he thought that it was because the men were more easily satisfied, and did not object to work a long day. It was not that they were more intelligent, but that they were more content, working morning, noon and night, and in that way they gave much better results.

Mr. Sharpe had said, let them enlarge the bucket of the bucket dredger. That was all right in soft material, but in rock work they had to be very careful not to enlarge the bucket. Mr. Sharpe had also said that his experience was that the output of suction dredgers was not reduced as much as 50 per cent. when working in gravel. It was very difficult to arrive at what the reduction was in dredging below the water surface, for the reason that the output of material might be 25 per cent. less, but the other 25 per cent. of stones was left in the bottom. When one came to unload a barge which had gravel and sand in it, there was a fair means of testing, and invariably it was found that the output was reduced 50 per cent. At Rosslare he believed the contractors found that their output was greatly reduced when they got into anything like gravel. He knew the Preston river fairly well, and he was not surprised to hear that something similar in the way of land reclamation had been done. It could not be put quite in the same class as the work that he had been engaged upon, because the length would be so much shorter, and probably the dredger did not cut its own flotation or reclaim land to a given level. He had known other places in which contractors had experimented on similar lines, but circumstances had proved entirely unfavourable. He could think of a place in Scotland where it was tried, and had to be abandoned through circumstances beyond control.

Mr. Maurice Wilson had asked whether he (the author) went under water to inspect the men. His reply was that, of course, he went under water sometimes, and he should be sorry to be left in charge of men whom he could not see. He was against the use of the diver, because he had to work under so many disadvantages, cumbered with a bulky dress, ofttimes in a strong current, and at this time of year with cold hands whilst his body would be perhaps in a bath of perspiration. There were many other points, and the more the engineer went down the more he would see. With regard to explosives, he might say that he did not often use dynamite. He was using gelignite at the present time, because there was far less risk in handling it, and it was far less likely to run or become scattered about the floor. The advantage of dynamite was that it would lose its power after about twenty-four hours' immersion, at all events, it went off more quickly than gelignite. That was a point in favour of dynamite in the event of a miss-fire, but still he did not use it. The Lubecker machine was made by a firm in Lubeck in North Germany. He was there about three years ago, and the speciality of the firm was to make that machine. It was the German form of the steam-navvy. The same machine, or one very similar to it, had been used at Heysham. It was nothing more than a dry-land dredger, and it could not be very well applied on ordinary works. They were very suitable for cutting a canal, one going down one side and one on the other, and the longer the canal the more economically they would work.

Mr. Matthews referred to the zero of the gauge. He did not know whether Mr. Matthews meant that zero should be at low water of ordinary spring tides. (Mr. Matthews assented.) He (Mr. Blake Thomas) knew of one or two gauges that were fixed like that, and they were of no use to a man navigating a ship, because they did not indicate the draught. Again, he objected to it in making a survey, because, assuming that they had a bank of ground which came into the survey and that the level of it was above zero, they would then have to record it by means of a "plus" sign, and all levels which fell below zero would have to be recorded by a "minus" sign. He found that it was very much more convenient to put zero anywhere as long as it came below any point to be recorded, so that the readings might all be "plus" and not "minus." The adoption of this plan would avoid much confusion. As to the use of a telephone in a diving bell, he had found it quite successful, and he should be sorry to have to do without one.

Perhaps, in stating that the rapid slewing of a crane would cause a diving bell to capsize, he was going beyond the mark. He meant to infer that if the bell swayed and lost its stability it would make matters unpleasant for the men in the bell, and they would get somewhat uneasy.

He did not think that he would dive out of a bell if it were down in water 100 feet deep, but a diving bell did not often go so deep as that. He should not hesitate to dive out of a bell if it was in a depth of 40 feet, if he thought the occasion called for it, but not as a regular thing.

He had never tried to plot a contour of dredging areas. It gave an unsatisfactory chart. He found it better to divide the area into squares and take an average of the squares.

Obituary.

James Chambers, whose death occurred on May 25, 1906, but was not reported until January 30, 1907, was born on June 23, 1835. He was for some years engaged as an engineering contractor, after which he was for thirteen years assistant foundry manager at the Staveley Iron Works, subsequently being appointed manager of the Stanton Iron Foundry, Stanton-by-Dale. Mr. Chambers was elected a member of the Society in 1886.

William Thomas Sugg, whose death took place on February 28, 1907, was born in Westminster in 1833. He served his apprenticeship with his father, who in 1838, established a gas meter and fittings works in Marsham Street. Under the late Mr. Thomas Livesey, he acquired a knowledge of the manufacture of gas. In 1858, Mr. Sugg joined his father in his business, which he acquired on the death of the latter in 1862. In course of time the expansion of the business led to the vacation of the Marsham Street premises and to the establishment of the Vincent Works, in Regency Street, Westminster. The deceased gentleman's life was spent in the development of the science and practice of gas engineering. His great aim was to improve the illuminating qualities of coal gas, and the methods of its use, as well as to devise means for its employment for purposes other than illuminating, in both of which directions he was eminently successful. Mr. Sugg was a prolific contributor to the literature of that branch of engineering, of which he was so eminent and so practical an exponent. He read two papers before the Society of which he was one of the oldest members, having been elected in 1861.

Patrick Doyle, whose death occurred on March 27, 1907, at Bombay, was born in 1849, and entered the Civil Engineering College, Madras, in 1864 at the early age of 15, passing out about two and a half years later, after graduating with honours. He at once obtained admission into the Madras P.W.D., and was soon placed in charge of two of the most important sub-divisions in the Madras Presidency. He subsequently held the appointment of Chief Superintendent of Public Works of Perak. Following this he went to Australia, and held several appointments in Queensland. He went thence to China, and returning to India in 1883, was appointed District Board Engineer in the Bellari and Godavari Districts of the Madras Presidency, subsequently practising as a consulting engineer in Oudh. It is, perhaps, in connection with the literature of the profession that Mr. Doyle will be most widely remembered, for he was a prolific and at the same time an authoritative writer on engineering subjects, as many technical and scientific journals bear witness. He was the founder and editor of "Indian Engineering," of which journal he was also the proprietor. Mr. Doyle was a member of several technical institutions, and was elected a member of the Society in 1878.

HENRY HARRIS LAKE, who died on April 22, 1907, had been a member of the Society of Engineers for twenty years. He was a member of the firm of Haseltine Lake and Co., of Southampton Buildings, Chancery Lane, consulting engineers and patent agents.

SIR BENJAMIN BAKER, K.C.M.G., LL.D. Edinburgh University, F.R.S., whose death took place at his Pangbourne residence, on May 19, 1907, was one of the most able leaders of the engineering profession, and received the K.C.M.G. on the opening of the Forth Bridge, of which he was, with the late Sir John Fowler, joint engineer. The principal features of the structure are the cantilevers about one-third of a mile in length united by a central girder 350 feet long, the bridge carrying the railway high above the sides of the valley of the Forth, and the piers being nearly the height of St. Paul's Cathedral, London. When tested on January 21, 1890, two trains weighing 1800 tons and each 1000 feet in length, were driven to the middle of the north cantilever and back, and the deflections were in exact accordance with the calculations of the engineers. The bridge took seven years to construct, and is one of the largest railway bridges yet built. Sir Benjamin also designed and constructed many other important works both in this country, Egypt, Canada and the Cape. He was a member of the International Commission of Experts, appointed to report on the original plans for the Assouan dam, and having been consulting engineer when the work was put in hand, was recently referred to as to the possibility of raising the height of the dam. Lord Cromer expressed his appreciation of the great services rendered by Sir Benjamin in the solution of the problem of the reinforcement of and addition to the structure. At the conclusion of the work at

Assouan he received a K.C.B., and first class Order of the Medjidieh from the Khedive. Sir Benjamin Baker was a Past President of the Institution of Civil Engineers, and was Civil Member of the Ordnance Committee, and on the death of the late Sir Frederick Bramwell, became Senior Civil Member, taking a prominent part in all branches of its work. He served on the Special Committee as to the possible interference with the observatory work at Greenwich by the construction of the Greenwich Electric Generating Station of the London County Council. He was also a member of the Engineering Standards Committee, was elected an Hon. Member of the Society of Engineers in 1889, and was also one of its trustees.

JAMES FAVRE, died in Japan on June 13, at the age of 38. He received his early engineering training at Zurich, and subsequently was in charge of the testing departments at Creusot works for the verification of the manufacture of steel. In 1893 he was engaged at the Oerlikon Electric Works of Zurich in designing and estimating for electric lighting and power transmission. The following year he joined the firm of Favre Brandt, in Osaka, with whom he remained until his death, his work consisting of preparing engineering contracts, and the arranging of plants for the Japanese Naval and Military Departments. He became a member of the Society of Engineers in 1896.

PERRY FAIRFAX NURSEY was born in London on October 5, 1830, and died there on June 20, 1907, after a brief illness. After a general education at private schools, he entered in 1845 the office of the late Mr. John Addison, civil engineer, of Westminster, with whom he was engaged, during what was known as the "Railway Mania," until the early part of 1851. During that year he superintended some works of building construction, and from 1852 to 1857 was engaged as secretary and assistant engineer to several mining companies in Devon and Cornwall, notably the Britannia Gold Mines in North Devon, which yielded gold, but not in paying quantities, owing to the defective system of mercurial amalgamation being employed. It was, however, at that time the only known method of obtaining gold from the crushed ore.

From 1858 to 1861 Mr. Nursey was engaged with the late Mr. C. W. Ramie of Westminster, in working that gentleman's system of permanent way for railways, and was in practice on his own account during the latter part of the time. From 1862 to 1864 he was engaged with the late Messrs. Ordish and Le Feuvre, bridge and roof engineers of Westminster, managing one department of their business. During that time Mr. Nursey occasionally contributed articles to "The Engineer," and on January 1, 1865, he accepted the appointment of editor of the "Mechanics' Magazine," which was the oldest engineering journal, having been established in the year 1823. He vacated the editorial chair at the end of 1869 when the paper changed hands, but he continued to write for it. During the period of his editorship, he practised as a consulting engineer, and in 1870 he returned to Westminster and continued his practice. In 1871, he accepted the appointment of secretary of the Society of Engineers, of which he was elected a member in 1858. In conjunction with the secretarial work he continued to practise as a consulting engineer, and from 1870 to 1879 he was on the staff of "Engineering."

In July of 1879, he resigned the secretaryship of the Society, having accepted the appointment of editor of the metallurgical journal "Iron," which position he held until June 1893, when the paper changed hands. He carried on his practice as a consulting engineer and technical expert concurrently with his editorial work on "Iron," and when the paper changed proprietors, he continued his private practice, occasionally contributing to the paper.

Upon resigning the secretaryship of the Society of Engineers, in 1879, Mr. Nursey was presented by the members with a testimonial and illuminated address, a silver salver with an inscription, and a purse of £150. He was elected President of the Society in 1886. Upon the death of the Honorary Secretary and Treasurer in 1894, Mr. Nursey was unanimously appointed to that office, which office, however, he vacated at the commencement of the year 1898, when he again accepted the secretaryship which became vacant by the resignation of the secretary Mr G. A. Pryce-Cuxson. Mr. Nursey carried on his private practice concurrently with his secretarial work.

He was a liberal contributor to the "Transactions" of the Society, having read no fewer than twenty-four papers on various professional subjects, including his inaugural address as President. For five of these communications read before he became officially connected with the Society, he was awarded premiums of books.

Mr. Nursey was engaged in a number of patent cases as technical expert, and had considerable experience of explosives, having been at one time engineer in England to a German firm of dynamite manufacturers. He gave evidence before the Parliamentary Committee on explosives in 1874, appointed in connection with the Explosives Act, which was passed in 1875. He carried out several important blasting operations, including the removal of rocks in connection with the Jersey Harbour Works and the Douglas (Isle of Man) Harbour Works. He also chambered bore-holes, 5 inches diameter, in the chalk at depths of over 400 feet from the surface by blasting under heads of 300 to 350 feet of water, with the view of increasing the water-supply. In 1890 he removed the bases of several cast iron columns in the bed of the Thames at Wapping by blasting at high water, and in 1891 he demolished, by the same means, one of Brunel's 3-arch brick bridges over the Great Western Railway in the Sonning Cutting, near Reading, the bridge having to be removed for the widening of the line.

Mr. Nursey acted as technical correspondent of the "Times" for many years from 1871, having originally worked under Mr. Delane and the late Mr. Macdonald. He was elected a member of the Iron and Steel Institute of Great Britain in 1880, his proposer having been the late Sir Henry Bessemer.

WM. HENRY HOLTTUM, one of the Vice-Presidents of the Society, died on July 11, 1907, at the age of 56, after a short illness. He was elected a member of the Society of Engineers in 1888, and was a regular attendant at its deliberations up to a few weeks before his death. After serving his apprenticeship to Messrs. Ordish and Le Feuvre, of Westminster, he was engaged by Mr. W. Barns Kinsey for over 12 years. He had extensive experience of tunnelling and earth works on the Great Northern Railway, and of water supply on the Tilbury Railway. He was elected an Associate Member of the Institution of Civil Engineers in 1883, and in 1893 joined the service of the London County Council as Surveyor in the Engineers' Department, in which capacity he designed works of dock construction, river walls, and street improvements. He was Captain and, for twenty years, Quartermaster, in the 1st Volunteer Battalion, Royal Fusiliers, having served for 2 years as a private and about 16 years as a non-commissioned officer in various useful capacities: in fact most of his leisure hours were devoted to the working of the Corps. In 1892, he contributed to the Society a paper on "The Use of Steel Needles in Driving a Tunnel at King's-Cross."

Mr. BASIL PYM ELLIS, whose death took place on October 5, 1907, was an Associate of the Institute of Civil Engineers, and became a member of the Society of Engineers in 1886. He was partner in the firm of Messrs. John Aird and Sons, with which firm he had been connected during the past forty years. Among other work he was engaged in the construction of the Millwall Docks, various waterworks, including those of Southwark and

Vauxhall, Birmingham and Colne Valley, and sundry railway contracts, the Greenwich and Woolwich Railway among the number. He undertook the construction of the Aldgate and Bishopsgate section of the Inner Circle, and, after becoming partner in the firm, took an active part in the contract for the construction of the Assouan dam.

FIFTY-THIRD ANNUAL GENERAL MEETING.

HELD AT
THE OFFICES OF THE SOCIETY, 17 VICTORIA STREET,
WESTMINSTER.

Monday, December 9, 1907.

JOSEPH WILLIAM WILSON, VICE-PRESIDENT,
IN THE CHAIR.

THE Minutes of the Fifty-Second Annual General Meeting, held December 10, 1906, were read, confirmed, and signed.

The chairman read the report of Messrs. P. F. Mackenzie-Richards and A. Wölheim, the scrutineers of the balloting papers for the election of the council and officers for the year 1908, appointed by him, and announced the names of the members who had been elected to office.

The secretary was instructed to convey, in writing, to the scrutineers, the thanks of the meeting for their services.

The chairman announced the premiums which had been awarded by the Council for meritorious papers read during the year. (See the Report of the Council, page 252.)

A vote of thanks to Mr. J. W. Wilson for his services as acting-president [the president being in China for the year], was passed by acclamation, and was acknowledged by Mr. Wilson.

A vote of thanks to the vice-presidents, council and officers for their services during the year 1907, and was acknowledged by Mr. D. A. Symons.

ANNUAL REPORT OF THE COUNCIL, 1907.

THE Council have the pleasure to report that the Society continues to maintain its satisfactory position in face of the continued professional depression. Notwithstanding this its finances are in a satisfactory condition, and the membership roll shows a slight advance on that of the preceding year. The losses from deaths, resignations and other causes amount to 37, which is the same as last year, whilst the number of new members and associates elected during 1907 aggregates 39 as compared with 40 in 1906.

THE MEMBERSHIP ROLL.

The following table shows the numbers on the roll of the Society at the end of the years 1905, 1906 and 1907 :—

Class.	Dec. 31, 1905.	Dec. 31, 1906.	Dec. 31, 1907.
Honorary Members	20	19	20
Ordinary Members	277	269	263
Ordinary Associates	116	121	121
Foreign Members	99	107	113
Foreign Associates	31	30	31
Totals	543	546	548

DEATHS.

Although the Council are able to report that the death roll of the Society during the past year has been no heavier than it was in the previous year, they regret to say that it includes the names of two of its oldest members, also two Hon. Members, and a Vice-President. The two Hon. Members were Sir Benjamin Baker, K.C.B., F.R.S. (elected in 1869), who died on May 19, 1907, and Lord Kelvin, LL.D., F.R.S. (elected in 1890), who died in December last; Mr. William Henry Holttum (elected a member in 1868)—was a Vice-President at the time of his death, which took place on July 11, 1907.

It was a matter of universal regret that the Society should lose two such old members as Mr. Perry F. Nursey, our late Secretary, who was elected in 1858, served as President in 1886, was Hon.

Secretary and Treasurer from 1895 till 1898, and who died on June 20, 1907, having acted as secretary since the year 1899; and Mr. W. T. Sugg (elected in 1861), who died on February 28, 1907. Further details as to the great services rendered to the Society by Mr. P. F. Nursey will be found in the report of the ordinary meeting of October 7, 1907, when special reference was made to the subject from the chair.

As secretary, in succession to Mr. Nursey, the Council have appointed Mr. A. S. E. Ackermann, B.Sc. (Engineering), Assoc. M. Inst. C.E., and from the experience obtained up to the present time, the Council are confident that their selection will be fully justified. Mr. Ackermann has already exhibited a most praiseworthy enthusiasm in the interests of the Society, and our future prospects under his administration are extremely promising.

FINANCE.

The accompanying Statement of Accounts (see pages 255 and 256) shows a considerable improvement on that of the previous year, the excess of income over expenditure amounting to 98*l.* 7*s.* 9*d.*, which has been carried to the accumulated fund account. That fund now amounts to 859*l.* 16*s.* 7*d.*, of which about 606*l.* is invested in Railway Stock.

The Council have thought it wise to take advantage of a successful year to write down the value of the investment in L. and N. W. Railway Debenture Stock from 647*l.* 4*s.* 2*d.*, the amount originally paid, to 606*l.*, which represents more nearly the present market value of the Stock.

PAPERS.

The following is a list of the papers read during the year :—

Feb. 4.—President's Inaugural Address, by Mr. Richard St. George Moore.
Mar. 4.—The Connaught Bridge, Natal, by Mr. Edward John Stead.
April 8.—The Renard and Sourcouf Road-Train System, by B. H. Thwaite and R. F. Thorpe.
May 6.—Waterworks Construction in America, by Ernest Romney Matthews.
June 3.—Working Experiences with Large Gas Engines, by Cecil H. St. George Moore.
Oct. 7.—Liquid Fuels for Internal Combustion Engines, by R. W. A. Brewer.
Nov. 4.—Bridle Roads in the West Indies, by H. C. Huggins.
Dec. 2.—Subaqueous Operations, by H. Blake Thomas.

PREMIUMS.

The Council have awarded Premiums to the following authors for the papers named in the foregoing list, viz. :—

1. To Mr. R. W. A. Brewer, the President's Gold Medal.
2. To Mr. E. J. Stead, the "Bessemer Premium" of Books.
3. To Mr. C. H. St. George Moore, a "Society's Premium" of Books.
4. To Mr. H. Blake Thomas, a "Society's Premium" of Books.

ATTENDANCES AT MEETINGS.

The Council regret that there has not been any marked improvement in the attendances at the Ordinary Meetings of the Society. Considering the excellent character of the papers provided, the attendances were by no means proportional to the practical value of the papers and discussions. The Council would therefore again impress upon the members and associates the desirability of attending the meetings in their own interest, as the title of a paper does not always indicate either its practical value or that of the discussion by which it is followed.

VISITS TO WORKS.

During the vacation the following works were visited, descriptions of which appear on page 151 :—

June 19, 1907.—The New Reservoirs of the Metropolitan Water Board, Honor Oak, and
Sept. 25, 1907.—H.M. Dockyard, Chatham.

Upon each occasion the members were most cordially received, but the attendance was on neither occasion as large as the Council desired or expected. They therefore desire specially to impress upon the junior members and associates the practical value of these visits to works, and to point out the desirability of attending them whenever they are able.

ANNUAL GENERAL MEETING.

The fifty-third Annual General Meeting of the Society was held on December 6, and the report of the proceedings appears on page 249.

ANNUAL DINNER.

The fifty-third Annual Dinner of the Society was held at the Hotel Cecil on Wednesday, December 11, 1907. Owing to the absence of the President, Mr. R. St. George Moore, in China, the chair was taken by Mr. J. W. Wilson, Past-President and President-Elect. Among the visitors were Sir William Matthews, K.C.M.G., President of the Institution of Civil Engineers; Sir Alexander

Binnie, M. Inst. C.E., Past-President of the Institution of Civil Engineers; Sir Edward Raban, K.C.B., R.E.; Mr. W. Noble Twelvetrees, M. Inst. M.E., President of the Civil and Mechanical Engineers' Society; and Captain Riall Sankey. The speeches were interspersed with some excellent musical items supplied by Mr. Murray Rumsey and his artistes.

Business Directory and Employment Register.

Particulars of this have already been sent to members, and there has been a considerable response, but much still remains to be done before a complete record of the leading features of the work of every member is collected. Such a record will prove of great value, as it will enable the secretary, when inquiries are made to him for the names of engineers having any particular class of experience, or articles of manufacture for sale, to give inquirers the names of members who may be able to satisfy their requirements. For the guidance of those who have not yet sent in the information desired, it may be mentioned that these particulars should be entered neatly on a 5-inch by 3-inch card-index card, the member's surname being printed in block type at the top left hand corner, followed by the Christian names age, date, telephone number, telegraphic address, and postal address. The leading feature of his work, or in the case of a manufacturer, particulars of the articles manufactured by him, should then be stated.

Exchange Transactions.

The Society continues the exchange of Transactions with the following Institutions, the volumes being available for reference by members and associates at the Society's offices.

The Institution of Civil Engineers.
The Institution of Mechanical Engineers.
The Institution of Electrical Engineers.
The Institute of Naval Architects.
The Iron and Steel Institute.
The Surveyors' Institution.
The Association of Municipal and County Engineers.
The Civil and Mechanical Engineers' Society.
The Junior Institution of Engineers.
The Institution of Mining and Metallurgy.
The Royal Engineers' Institute.
The Incorporated Institution of Gas Engineers.
The Royal Institute of British Architects.
The Chartered Institute of Patent Agents.
The Royal Society of Arts.
The Liverpool Engineering Society.
The Cleveland Institution of Engineers.
The North East Coast Institution of Engineers and Shipbuilders.
The North of England Institute of Mining and Mechanical Engineers.
The South Wales Institute of Mining Engineers.
The Institution of Engineers and Shipbuilders in Scotland.
The Institution of Civil Engineers of Ireland.
The French Institution of Civil Engineers.
The Canadian Civil Engineers' Society.
The Victorian Institute of Engineers.
The Engineering Association of New South Wales.
The American Society of Civil Engineers.
The Municipal Engineers of New York.
The Association of Engineering Societies.
The Smithsonian Institution.
The Franklin Institute.

Journals and Magazines.

The library contains many books on engineering subjects, and, in addition, the following journals and magazines are supplied gratuitously by their respective proprietors, all being available for reference by the members.

American Machinery.
American Machinist.
Arms and Explosives.
Automotor Journal.
British Architect.
Builder.
Building News.
Cassier's Magazine.
Commercial Motor.
Concrete.
Contract Journal.
Electrical Review.
Electrician.
Engineer.
Engineering.
Engineering Magazine.
Engineering Times.
Indian Engineering.
Indian and Eastern Engineer.
Journal of Gas Lighting.
Local Government Journal.
Local Government Officer.
Machinery.
Machinery Market.
Marine Engineer.
Mechanical Engineer.
Mechanical World.
Motor Traction.
Page's Weekly.
Sanitary Record.
Shipping World.
Society of Arts Journal.
South African Engineering.
Steamship.
Surveyor.
The Metal Industry.
The Quarry.
The Tramway and Railway World.
Water.

The secretary hopes, during the year 1908, to be able to prepare a card-index catalogue of the books in the library. This catalogue will be alphabetically arranged under "Authors" and under "Subjects," and should considerably enhance the value of the library to those members who are in a position to avail themselves of it.

The Council, in conclusion, would impress upon the members the desirability of using their best endeavours to promote the interests of the Society. This may be done by contributing papers embodying the latest phases of engineering practice; by attending the ordinary meetings, and taking part in the discussions; by joining in the vacation visits; and by introducing duly qualified gentlemen as members or associates.

January, 1908.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED DECEMBER 31, 1907.

Dr.

Year ended 31 Dec., '06. £ s. d.	EXPENDITURE.		£ s. d.
223 10 2	To Printing Transactions	£185 19 7	
19 8 6	*Less* Sales	13 0 6	
			172 19 1
204 1 8			
122 16 0	,, Rent of Offices and Hire of Rooms		122 16 0
264 0 0	,, Salary of Secretary and Clerical Assistance		231 0 0
36 12 5	,, Stationery and General Printing		45 17 7
14 18 6	,, Reporting Meetings		15 4 6
7 8 0	,, Refreshments for Members at Ordinary Meetings		6 5 4
21 12 11	,, Fuel, Lighting, Office Cleaning and Repairs		20 1 0
49 14 9	,, Postages, Telegrams, Carriage, and General Expenses		42 4 7
89 6 1	,, Dinner—Balance		11 17 10
– – –	,, Law Charges		5 16 3
– – –	,, Depreciation on Office Furniture		4 16 6
– – –	,, Donation to Mrs. Nursey, Widow of late Secretary		25 0 0
9 0 0	,, Balance carried to Accumulated Fund Account—Excess of Income over Expenditure for the year		98 7 9
£810 10 4			£802 6 5

Cr.

Year ended 31 Dec., '06. £ s. d.	INCOME.	£ s. d.
770 14 0	By Subscriptions for the Year, *less* amounts written off	728 3 6
101 17 0		
668 17 0		
7 6 8	,, Life Subscriptions—proportion for 1907	6 12 0
53 0 6	,, Admission Fees (including £8 18*s.* 6*d.* unpaid at date)	49 7 0
3 3 3	,, Interest on Deposit	1 13 0
17 5 4	,, Interest on Investment (L. & N. W. Rly. Debenture Stock)	16 10 11
60 17 7	Balance.	
£810 10 4		£802 6 5

LIFE MEMBERSHIP FUND.

£ s. d.		£ s. d.
7 6 8	To Revenue Account—proportion for the year	6 12 0
66 0 5	,, Balance to be carried to next Account	59 8 5
£73 7 1		£66 0 5

£ s. d.		£ s. d.
73 7 1	By Balance brought from last Account, being unexhausted Balance of the Fund on 31st December, 1906	66 0 5
£73 7 1		£66 0 5

PREMIUM FUND.

£ s. d.		£ s. d.
14 0 0	To Premiums	15 18 9
32 4 10	,, Balance to be carried to next Account	32 1 7
£46 4 10		£48 0 4

£ s. d.		£ s. d.
30 9 4	By Balance brought forward from 31st December, 1906	32 4 10
10 10 0	,, President's Donation	10 10 0
5 5 6	,, Interest to date, Bessemer Trust Fund Investment	5 5 6
	NOTE.—£185 North Eastern Railway Stock is held in trust to secure payment of the late Sir H. Bessemer's premium.	
£46 4 10		£48 0 4

BALANCE SHEET, DECEMBER 31, 1907.

Year ended 31st Dec. '06. £	s.	d.	LIABILITIES.	£	s.	d.	£	s.	d.
59	12	7	Sundry Creditors				25	0	9
66	0	5	Life Membership Fund				59	8	5
32	4	10	Premiums Fund				32	1	7
50	0	0	Special Fund				25	0	0
0	0	0	"Nursey Memorial Fund"				25	6	6
0	0	0	J. Bernay's Legacy				25	0	0
26	5	0	Subscriptions Received in Advance				34	2	6
			Accumulated Fund:—						
			Balance at 31st December, 1906	£802	13	0			
802	13	0	*Add* Excess of Income over Expenditure for the year ended 31st December, 1907 ..	98	7	9			
							859	16	7
£1,036	15	10					£1,085	16	4

Year ended 31st Dec. '06. £	s.	d.	ASSETS.	£	s.	d.	£	s.	d.
200	13	0	Subscriptions in Arrear	£240	6	0			
3	3	0	Admission Fees in Arrear	8	18	6			
203	16	0		249	4	6			
100	0	0	*Less* Reserve against Bad Debts	100	0	0			
103	16	0					149	4	6
90	1	5	Cash at Bank				166	4	4
50	0	0	Special Account				25	0	0
2	10	2	„ in hands of Secretary				5	0	11
647	4	2	Investment—£606 London & North Western Railway Company 3 per cent. Debenture Stock				606	0	0
40	0	0	Office Furniture				43	8	6
40	0	0	Library				40	0	0
38	2	0	Stock of Transactions				38	19	6
25	2	1	Sundry Debtors				11	18	7
£1,036	15	10					£1,085	16	4

Audited and found correct,

(Signed) SAMUEL WOOD, F.C.A.,
Hon. Auditor.

10th January, 1907.

SOCIETY OF ENGINEERS.

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